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Soil Survey (Reconnaissance) of The Columbia Basin Area Washington

By

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State College of Washington

Bureau of Chemistry and Soils

In cooperation with the
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SOIL SURVEY

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AREA SURVEYED

The Columbia Basin area is in the south-central part of the State of Washington (fig. 1) and occupies the greater part of the so-called "Big Bend Country", a region bounded on the north and west by Columbia River, between the mouth of Spokane River and the mouth of Snake River, and on the south by the latter stream. The area surveyed includes all of Franklin County, nearly three quarters of Grant County, somewhat more than one half of Adams County, about 8 square miles in the southwest corner of Lincoln County, and about 327 square miles in the extreme western part of Walla Walla County, a total area of 3,084,160 acres, or 4,819 square miles.

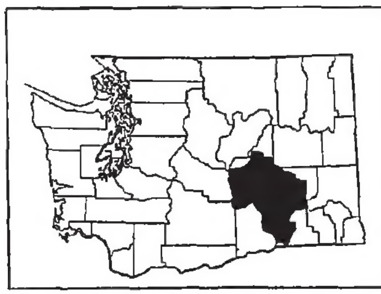

FIGURE 1.—Sketch map showing location of the Columbia Basin area, Washington.

The boundaries of the area are formed in part by natural geographic features and in part by township and section lines. From the town of Trinidad, in the western part of Grant County, eastward across Grant, Lincoln, and Adams Counties to near the town of Hillcrest, and from Hillcrest southward to the intersection of the northern boundary of Franklin County with Palouse River, the boundaries follow county and township lines; from this point Palouse and Snake Rivers form the eastern and southern boundaries as far south as the northern line of T. 10 N.; thence the boundary follows that township line eastward for about 9 miles; thence south for about 6 miles to Touchet River. Touchet River and Walla Walla River, to its junction with Columbia River, form the remainder of the southern boundary, and, from the mouth of Walla Walla River northward to Trinidad, Columbia River forms the entire western boundary.

The area is in general a smooth westward-sloping plain, deeply but very imperfectly dissected and interrupted by a few mountainlike ridges, the most important of which are Saddle Mountains and Frenchman Hills.

Columbia River flows in a deep valley throughout its entire course along the western boundary of the area. For practically the entire distance from Trinidad to the southern edge of Saddle Mountains the stream is held in a narrow rock-walled gorge, the only pro-

nounced break being at the mouth of Crab Creek. From Saddle Mountains southward, the east bank of Columbia River follows alternating reaches of nearly vertical cliffs and low terraces.

A comparable surface relief occurs along Snake River Valley. The short stretch of Walla Walla River that forms part of the southern boundary meanders through a narrow belt of river-bottom soils.

The terraces along the larger streams lie at elevations ranging from only a few feet to as much as 50 feet above the normal level of the stream. Near the mouth of Walla Walla River the stream terraces are 300 feet above sea level, and at Trinidad the elevation of the river flood plain is about 600 feet. The greater number of these lower stream terraces and bottoms are bounded by the river on one side and by vertical or steeply sloping terraces, which rise to the general level of an elevated plain, on the other. In the vicinity of Pasco the river terraces have a maximum elevation of about 50 feet above the normal water level of the river, and they merge with the higher lands through more or less perceptible slopes.

In Walla Walla County, prominent terraces front the channels of the larger streams at distances ranging from a few rods to as much as 3 miles. From the tops of these terraces, the slope is gradual to the northeast, until a maximum elevation of about 1,250 feet above sea level is reached in the northeastern corner of the part of this county included in the surveyed area. Much of this plain is very rough and hummocky, and it is deeply cut by local drainage channels.

In Franklin County the surface relief above the river bottom lands is roughly divided in two parts by more or less distinct terrace boundaries. East of Pasco the Snake River Flat is a very uniformly surfaced area lying about 300 feet above the river. It averages about 3 miles in width and is bounded by a rough and eroded terrace which rises to an elevation of 300 feet above the flat, or about 1,000 feet above sea level. North of Pasco the terrace is bordered by a series of very irregular dunelike slopes which rise gradually for several miles and culminate in areas having a more uniform surface at an elevation of about 350 feet above the river terrace. These higher areas, which have a general rise to the northeast, range from about 500 to about 1,600 feet above sea level.

Throughout the greater part of the southern half of Franklin County, above the river terraces, are either extensive areas having a pronounced dunelike surface relief or areas in which extensive stream erosion has developed a complicated series of narrow hogbacked ridges with very steep slopes between the local drainage courses. In the northern half of the county, west of the main line of the Northern Pacific Railway, is a series of rather flat-topped mesas, or tablelands, of varying extent, which are everywhere characterized by vertical or very steep sides. The elevation of the mesas ranges from about 900 to 1,200 feet above sea level, and the uniformity of the general slope is such as to give the impression of a continuous plain, wherever the viewpoint is such that the intervening drainage courses are not visible. A narrow strip of deeply eroded land lies north of Washtucna Coulee, and it gradually merges into a uniformly gently rolling plain along the northern boundary of the county.

In Grant County, the most striking topographic features are Saddle Mountains and Frenchman Hills, which extend from east to west

entirely across the county. Saddle Mountains, rising about 2,400 feet above sea level and about 1,600 feet above the surrounding plains, have smooth, gradual, but sharply dissected, southward slopes and steep or precipitous northward slopes. Frenchman Hills are less rugged, the slopes rising gradually from the north and south to the axes of the hills, which are at an elevation of a little more than 1,600 feet above sea level. At the western end the hills terminate in steep cliffs adjacent to the Columbia River Valley. From Frenchman Hills to the northern boundary of the area, the relief is that of a very uniform plain. On the west, this plain is terminated by a series of vertical escarpments and reentrant gorges of basalt that form the rugged canyon of Columbia River. To the east, the surface of the plain is considerably broken by areas of dunes in the southern part and by prominent gravel terraces in the northern part. An old stream channel lies in the lowest part of this plain, its deepest part being occupied by a long narrow body of water known as Moses Lake. The elevation of the plain ranges between about 1,000 and 1,300 feet above sea level. East of Moses Lake, the land surface rises gradually to the vicinity of Wheeler, where a low poorly defined terrace marks the western boundary of a slightly higher rolling plain extending eastward into Adams County, nearly to the eastern boundary of the area. North of Quincy, Winchester, and Moses Lake, the relief becomes more broken, and, with steadily increasing elevation, the surface is marked by a series of sharply rolling ridges that extend beyond the boundaries of the area.

Throughout Adams County and that part of Lincoln County included in the surveyed area, the physiography is that of a plain rising gradually toward the northeast. This part of the area is covered by an intricate system of small drainage courses, each of which is bordered by areas of sharply eroded land, and the intervening territory is a series of gently sloping and rolling ridges. This plain is terminated near the eastern boundary of the area by a series of eroded terrace slopes, and the lower lands to the east are part of an extensive area that is marked by small local mesas and narrow rock-bound stream channels.

The rivers in and along the boundaries of the area are perennial, and the smaller drainage courses within the area are intermittent, carrying water for only short periods during the spring months or for a few hours following local storms. The largest of these streams, Crab Creek, carries water throughout the year only in parts of its course, east from Marlin for a distance of several miles and from the lower end of Moses Lake southward beyond Corfu, where the underground water has been forced to the surface by the underlying rock, but the flow soon disappears in the sandy bed of the stream. Similar conditions exist along Esquatzel Coulee in one or two places between Eltopia and Connell. Smith Canyon, Rye Grass Coulee, and Washtucna Coulee are examples of confined drainage, and northwest of Page the channels of a number of small coulees have been completely obliterated by extensive areas of sand dunes.

The Columbia Basin area is practically treeless, the only extensive growth of larger vegetation occurring along Walla Walla and Touchet Rivers, where fairly dense natural stands of cottonwood, willow, and underbrush grow. Along Columbia River, the only trees

are in a few small scattered stands of cottonwoods and an occasional group of junipers, which parallel the banks of the streams. In the western and southern parts of the area, where the rainfall is low and the soils sandy and porous, a semidesert type of vegetation is extensively developed, which consists of sagebrush, rabbitbrush, thorny sage, and other small plants that develop under arid conditions. On the higher plains, a variety of grasses constituted the greater part of the vegetation prior to the utilization of the land for grain farming, and sagebrush was commonly found only in the coulee bottoms.

The expedition of Lewis and Clark (1803-6) brought to the eastern part of the United States the first knowledge of the interior of the northwest country. The establishment of one of the trading posts of the Hudson Bay Co. near the mouth of Walla Walla River in 1825 undoubtedly marked the first white settlement in eastern Washington and in the Columbia Basin area. In 1842 the Webster-Ashburton Treaty definitely allotted the area now covered by the eastern part of the State of Washington to the United States. About the same time a band of missionaries, under the leadership of Marcus Whitman, established a small settlement along Walla Walla River in the vicinity of the present city of Walla Walla. Wallula is the oldest settlement in the area, having been established in 1863 when the Government purchased the holdings of the Hudson Bay Co. and established a fort. The old town was removed to its present site about 1883. The first settlement in Adams County was made along Cow Creek about 1865, and a settlement was made at the present site of the town of Marlin in 1872.[1]

Prior to 1880 the settlement of the area was confined to a few small scattered hamlets which developed following the opening of the region for cattle grazing. The Walla Walla branch of the Northern Pacific Railway was constructed in 1871, extending to the present site of Ainsworth Junction, and in 1885 the main line was completed entirely across the area. The Great Northern Railway was constructed across the northern part of the area in the early nineties. With the facilities afforded by these transportation routes and with the knowledge that the plains were adapted to a certain form of agriculture, a sudden increase in population took place, and new towns appeared throughout the area. Between 1890 and 1900 the population of Adams County increased from 2,098 to 4,840, or about 130 percent. Its present population, according to the 1930 census, is 7,719.[2] Douglas County, which included Grant County in 1900, increased in population about 55 percent for the 10-year period from 1890 to 1900. The population of Grant County in 1930 was 5,666. Franklin County suffered a 30 percent loss of population between 1890 and 1900, but in the following decade the population increased from 486 to 5,153, or nearly 1,000 percent. The population of Franklin County in 1930 was 6,137.

Pasco, situated near the junction of Snake and Columbia Rivers, is the largest town in the area and is an important railroad center. It is the county seat of Franklin County and has a population of 3,496. Lind, the county seat of Adams County, has 730 inhabitants. It is located on the main lines of the Northern Pacific Railway and

[1] HISTORY OF THE BIG BEND COUNTRY. 1,024 p., illus. 1904.
[2] Soil survey reports are dated as of the year in which the field work was completed. Later census figures are given whenever possible.

the Chicago, Milwaukee, St. Paul & Pacific Railroad and serves a wide extent of farming country. Ephrata, the county seat of Grant County, is located in the northwestern part of the area, on the main line of the Great Northern Railway. Numerous smaller towns occur along several lines of railroad, being local centers for extensive areas of dry-farming territory.

Columbia River is navigable for shallow-draft steamers as far north as White Bluffs Ferry and, although but little used at present, the lower course of the river offers a potential route for water transportation to ocean shipping ports. Snake River is navigable as far as the town of Lewiston, Idaho.

Two surfaced highways extend from east to west entirely across the area, and a number of local roads between the larger towns have also been surfaced. Dirt roads traverse almost every section, and, with the exception of short periods in the fall, when traffic is heavy, most of them are maintained in excellent condition.

The principal markets for the agricultural products of this part of the State are the Pacific coast towns, Portland and Seattle. Early fruits and vegetables, produced in the Pasco and Burbank districts, find a ready market throughout the Northwest, and later fruits, such as apples, peaches, and melons, are shipped to intermountain or eastern markets.

CLIMATE

The Columbia Basin area is in a distinctly arid region. The average annual precipitation ranges from about 6 inches in the southern part of the area to a little less than 13 inches near the extreme eastern part. The heaviest precipitation normally occurs during the winter and spring, the summer months usually passing with no appreciable rainfall. Temperature conditions are comparable to those characteristic of arid regions in the Temperate Zone. Not only is the seasonal range of temperature wide, but the diurnal changes may be strikingly apparent at any time of the year. The wind movement also is characteristic of regions of low rainfall, during the spring months being frequently high for days at a time, and during the summer months it is at times violent for a period of several hours. Severe electrical storms are rare. Hailstorms commonly occur in some part of the basin during the spring months but are limited to rather narrow paths.

Under the present type of agriculture prevailing in the area, which is dominated by wheat growing without irrigation, the agricultural prosperity is closely dependent on an ample and well-distributed rainfall. Years of low rainfall are reflected in crop failures and losses in the grain-growing districts and in wide-spread depressions in land values and industry throughout the entire area.

In irrigated districts where an adequate supply of water is available, rainfall is a minor factor in crop production, a deficiency in rainfall being met by the proper irrigation practice. Storms occurring at unusual or unfavorable times may be severe enough to interfere with farming operations.

Although the normal distribution and amount of rainfall is comparatively unimportant, temperature conditions within an irrigated district are a matter of real concern. The average length of the growing season, the dates of killing frosts, and the daily ranges in

temperature are important factors in determining the variety of crops that can be profitably produced.

Although variations in the surface relief of the Columbia Basin area as a whole are not great, certain topographic conditions exist that greatly influence the rather wide temperature differences in the different districts. The area is, topographically, rather sharply divided into a plains region and a river-terrace region. The last-named region is limited to a large extent to narrow areas of land lying between Columbia River and a rather abrupt escarpment that rises to the elevation of the plains to the east. Data showing the climatic conditions within the basin have been obtained from records of the United States Weather Bureau. These records are more or less complete. No records whatever are available for large areas, and very few stations have permanent records extending through a period of several years.

The climatic data given in tables 1, 2, 3, and 4, are compiled from the records of Weather Bureau stations, as follows: Kennewick, in Benton County, just across Columbia River outside the southwestern corner of the area surveyed; Trinidad, in the northwestern corner on Columbia River; Odessa, just outside the northeastern part; and Lind, in the east-central part. Precipitation records alone are available for Hooper, which is near the eastern boundary on Palouse River. The data given in these tables are believed to be representative of climatic conditions prevailing in the respective parts of the area.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Kennewick, Benton County, Wash.*[1]

[Elevation, 507 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1920)	Total amount for the wettest year (1916)	Snow, average depth
	°F.	°F.	°F.	Inches	Inches	Inches	Inches
December	34.3	71	−29	1.04	1.74	1.54	2.4
January	31.6	74	−21	.98	1.25	1.99	5.7
February	37.6	74	−10	.69	.11	2.43	2.9
Winter	34.5	74	−29	2.71	3.10	5.96	11.0
March	47.1	88	10	.48	.24	1.53	.3
April	54.6	95	21	.39	.37	1.17	.0
May	61.7	105	26	.46	.34	.25	.0
Spring	54.5	105	10	1.33	.95	2.95	.3
June	68.9	108	37	.41	.62	1.23	.0
July	76.2	114	38	.14	.00	.77	.0
August	73.7	115	38	.27	.03	.02	.0
Summer	72.9	115	37	.82	.65	2.02	.0
September	63.8	102	26	.37	.26	(2)	.0
October	53.7	88	15	.54	.11	.09	.0
November	42.2	78	−12	1.09	(2)	1.02	1.7
Fall	53.2	102	−12	2.00	.37	1.11	1.7
Year	53.8	115	−29	6.86	5.07	12.04	13.0

[1] Killing frost: Average last in spring, Apr. 20; average first in fall, Oct. 15; latest in spring, May 18; earliest in fall, Sept. 12.

[2] Trace.

TABLE 2.—*Normal monthly, seasonal, and annual temperature and precipitation at Trinidad, Grant County, Wash.*[1]

[Elevation, 900 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1929)	Total amount for the wettest year (1912)	Snow, average depth
	° F.	° F.	° F.	Inches	Inches	Inches	Inches
December	29.8	67	−13	1.24	0.78	0.64	8.7
January	27.6	65	−14	1.04	.52	2.84	7.8
February	33.2	57	−2	.96	.00	.97	5.2
Winter	30.1	67	−14	3.24	1.30	4.45	21.7
March	44.7	78	7	.40	.47	.53	.9
April	54.1	90	14	.38	.12	.82	(²)
May	62.2	98	30	.42	.50	.78	.0
Spring	53.7	98	7	1.20	1.09	2.13	.9
June	70.1	104	38	.51	.80	.90	.0
July	78.0	112	43	.29	.00	.62	.0
August	76.2	109	38	.14	.00	1.04	.0
Summer	74.7	112	38	.94	.80	2.56	.0
September	66.2	100	35	.36	.08	.16	.0
October	54.4	96	23	.51	(²)	1.11	.0
November	40.1	69	2	1.22	.00	1.24	3.5
Fall	53.5	100	2	2.09	.08	2.51	3.5
Year	53.0	112	−14	7.47	3.27	11.65	26.1

[1] Killing frost: Average last in spring, Apr. 7; average first in fall, Oct. 24; latest in spring, Apr. 25; earliest in fall, Sept. 23.
[2] Trace.

TABLE 3.—*Normal monthly, seasonal, and annual temperature and precipitation at Odessa, Lincoln County, Wash.*[1]

[Elevation, 1,590 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1930)	Total amount for the wettest year (1927)	Snow, average depth
	° F.	° F.	° F.	Inches	Inches	Inches	Inches
December	28.4	59	−24	1.25	0.76	0.22	5.5
January	26.4	60	−20	1.23	.67	1.27	6.5
February	32.6	68	−17	.96	.98	1.74	3.0
Winter	29.1	68	−24	3.44	2.41	3.23	15.0
March	41.3	83	6	.57	.26	.78	1.3
April	48.9	93	10	.62	.06	.37	.3
May	56.2	96	20	.86	.73	.68	(²)
Spring	48.8	96	6	2.05	1.05	1.83	1.6
June	63.7	102	29	.77	.93	.53	.0
July	71.1	111	32	.28	(²)	.03	.0
August	69.1	109	33	.34	.29	.16	.0
Summer	68.0	111	29	1.39	1.22	.72	.0
September	59.7	95	25	.65	.58	3.88	.0
October	49.2	86	10	.77	.47	.67	.2
November	37.7	73	−3	1.60	.86	2.89	2.4
Fall	48.8	95	−3	3.02	1.91	7.44	2.6
Year	48.7	111	−24	9.90	6.59	13.22	19.2

[1] Killing frost: Average last in spring, May 18; average first in fall, Sept. 23; latest in spring, July 14; earliest in fall, Aug. 26.
[2] Trace.

TABLE 4.—*Normal monthly, seasonal, and annual temperature and precipitation at Lind, Adams County, Wash.*[1]

[Elevation, 1,475 feet]

Month	Temperature: Mean	Temperature: Absolute maximum	Temperature: Absolute minimum	Precipitation: Mean	Precipitation: Total amount for the driest year (1929)	Precipitation: Total amount for the wettest year (1902)	Precipitation: Snow, average depth
	°F.	°F.	°F.	Inches	Inches	Inches	Inches
December	29.7	58	−11	1.19	1.15	2.49	4.8
January	29.3	61	−16	1.17	.45	1.68	6.4
February	33.2	63	−33	1.10	.12	2.53	5.7
Winter	30.7	63	−33	3.46	1.72	6.70	16.9
March	40.9	72	5	.68	.17	.63	1.6
April	50.0	88	20	.75	.24	1.79	.2
May	57.9	104	25	.88	.43	2.22	.0
Spring	49.6	104	5	2.31	.84	4.64	1.8
June	65.3	103	26	.78	1.35	.07	.0
July	73.3	116	35	.27	(²)	.58	.0
August	72.2	114	38	.40	(²)	.23	.0
Summer	70.3	116	26	1.45	1.35	.88	.0
September	61.1	98	23	.64	.02	.59	.0
October	51.1	90	19	.76	.23	.26	(²)
November	38.9	70	−11	1.58	.09	3.56	3.4
Fall	50.4	98	−11	2.98	.34	4.41	3.4
Year	50.3	116	−33	10.20	4.25	16.63	22.1

[1] Killing frost: Average last in spring, May 10; average first in fall, Oct. 7; latest in spring, May 27; earliest in fall, Sept. 12.
[2] Trace.

TABLE 5.—*Normal monthly, seasonal, and annual precipitation at Hooper, Adams County, Wash.*[1]

[Elevation, 1,083 feet]

Month	Precipitation: Mean	Precipitation: Total amount for the driest year (1903)	Precipitation: Total amount for the wettest year (1899)	Month	Precipitation: Mean	Precipitation: Total amount for the driest year (1903)	Precipitation: Total amount for the wettest year (1899)
	Inches	Inches	Inches		Inches	Inches	Inches
December	1.61	1.61	1.56	June	0.46	0.40	0.32
January	1.31	1.44	1.69	July	.43	.54	(²)
February	1.62	.17	2.59	August	.82	1.20	1.98
Winter	4.54	3.22	5.84	Summer	1.71	2.14	2.30
March	.58	.85	.45	September	.95	.45	1.11
April	.65	.06	.83	October	.86	.36	1.46
May	.92	.40	.95	November	2.08	2.19	2.10
Spring	2.15	1.31	2.23	Fall	3.89	3.00	4.67
				Year	12.29	9.67	15.04

[1] Killing frost: Average last in spring, May 9; average first in fall, Oct. 14; latest in spring, June 8; earliest in fall, Sept. 26.
[2] Trace.

Briefly, the Weather Bureau data indicate the following conditions: Not only are the highest monthly maximum temperatures developed in the lower lands along Columbia River, but the average length of the frost-free season is nearly 6 weeks longer than that of the plains region. Mean monthly temperatures are higher throughout the year in the district along Columbia River, and the mean annual temperature is about 3° higher than on the plains. The normal growing season on the plains is sufficient for maturing practically all temperate-climate crops. However, the daily range of temperature during the spring months indicates the probability of considerable risk of frost damage in producing commercial crops that start growing early in the spring. At this season periods of warm weather are often succeeded by short intervals when the temperature falls below the freezing point.

AGRICULTURE

Prior to the development of grain growing under dry-farming methods, the Columbia Basin area was a treeless plain covered with brush and grasses. The sandy desert plains supported a heavy growth of sagebrush, rabbitbrush, thorny sage, and bunch grass, whereas on the higher plains there was an almost complete absence of brush, except in the coulee bottoms, and the land supported a luxuriant growth of grasses. The first settlers were engaged solely in livestock raising, and their herds were allowed to range throughout the entire basin. The plains furnished the greater part of the grazing, and even in the desert areas grass was sufficiently heavy to carry a rather large number of cattle. The greatest difficulty with which the stockmen had to contend was the scanty water supply. The streams, with the exception of the rivers and Crab Creek, were dry during the greater part of the year, and abundant supplies of water were available at only a few places, such as Scooteney Lake, Washtucna Lake, and Moses Lake. The old trails leading to watering places may still be seen in parts of the basin where grain farming has not developed.

The stockmen, as well as the first settlers, located in the stream bottoms, where some native hay was harvested each fall and grain was grown on a small acreage. The uplands were considered worthless for the production of cultivated crops. In the late eighties some grain was grown on the plains in Adams County, and the success of this venture led to an extension of grain planting. Lack of transportation throughout the area, the idea that the soils would not produce crops, and the opposition of the cattlemen to the settlement of the country combined to restrict settlement.

As late as 1900, the country west of Soap Lake and Moses Lake remained uninhabited, and in that year the population of Franklin County was less than 500 persons. With the coming of the railroads and their advertising campaign and with the success of a number of dry-land farmers, both the rural and urban population rapidly increased. In the decade between 1900 and 1910, the acreage of improved farm land in Franklin and Adams Counties increased from about 280,000 acres to more than 1,000,000 acres. No data are available concerning settlement in Grant County for the same period, as Grant County was organized from a part of Douglas County in 1909, but by 1910 Grant County included nearly 500,000 acres of

improved farm land. From 1910 to 1930, the entire basin suffered a loss in population and a decline in the area of land under cultivation. These changes were caused in part by the removal of settlers who had settled on lands not adapted to dry farming and in part to a series of dry years when reduced yields of grain made it impossible for some settlers to continue farming operations. Many farmers who were able to continue their operations, either because of better methods of operation or because they were located on soils that were better adapted to grain production, secured the lands of less fortunate neighbors and increased the field of their operations. This was a change toward fewer but more extensive holdings, as shown by the census data for the last census period. In Adams County, the number of farms decreased from 1,263 in 1880 to 818 in 1930; in Franklin County, the decrease was from 620 to 354; and in Grant County, the number dropped from 1,607 to 787. The average size of farms increased greatly throughout the area.

The use of water for irrigation began along the larger coulees, where the flood waters in the channels were diverted for flooding the adjacent low-lying lands for the purpose of increasing the yields of native hay or for the production of small grains.

Prior to the settlement of the area, the railroads had been granted alternate sections of land for a certain distance on both sides of their right-of-way, and certain lands (sections 16 and 36 in each township) had been designated as State school lands. With these exceptions, the land was open to settlement under the Homestead Act. Filing of claims on these lands was most rapid in Adams and in the eastern part of Grant County. As late as 1900, practically the entire country between the Great Northern Railway and Frenchman Hills was still unentered public land. Franklin County was more slowly settled than the northern part of the area. At present only about 5 percent of the area remains as unentered public land. The distribution of ownership of the land within the basin is shown in table 6.

TABLE 6.—*Distribution of ownership of Columbia Basin land* [1]

County	Private	Government	State	Northern Pacific Ry.
	Percent	*Percent*	*Percent*	*Percent*
Adams	94	1	5	-----------
Grant	81	8	4	7
Franklin	83	6	4	7
Walla Walla	89	4.5	4.5	2
Average	86	5	4	5

[1] Table condensed from Columbia Basin irrigation project, p. 31, Columbia Basin Survey Commission, State of Washington, 1920.

Present-day agriculture within the basin is very definitely developed, using crops that are produced by dry-farming methods and those which are grown under irrigation.

From the beginning of the development of the high-plateau and desert-plains sections, wheat has been, and still remains, the leading dry-farmed crop. At first large areas of land were devoted to wheat where conditions of soil and rainfall were unfavorable. Experi-

ence has largely eliminated such districts, and the present wheat-producing area is largely in Adams County, the part of Grant County east of Moses Lake, the eastern half of Franklin County, and the more elevated parts of Walla Walla County lying between Touchet and Columbia Rivers.

Conditions of settlement and land utilization in the dry-farming districts of the area are illustrated by the township plats (fig. 2), which show the use of the land in the basin during 1923. The first plat is representative of conditions which exist from year to year in those sections where the soils and rainfall conditions make the production of grain possible without irrigation. The second plat illustrates conditions in a selected township, representative of large areas in the western part of the basin, where the soil is too sandy and the amount of rainfall too small to regularly produce grain profitably by dry-farming methods. This township was settled about 1900, when there was a rush of settlers to this part of the State, and is one of the townships in which the land was almost completely abandoned within a short time.

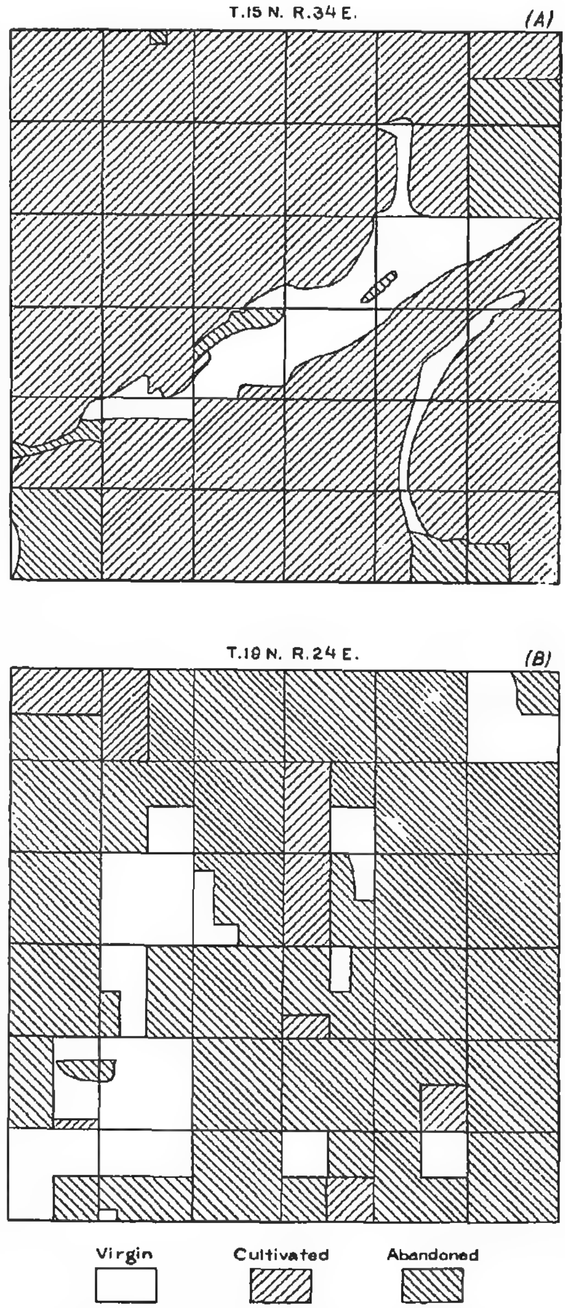

FIGURE 2.—Sketch maps showing utilization of land in two townships in the Columbia Basin area, Washington. *A*, Dry-farmed land, no irrigation necessary; *B*, land unprofitable for dry farming.

Table 7 indicates the use made of the lands included within the area during the summer of 1929. Cultivated land includes all irrigated areas, dry-farmed grain land, and land that was fallow during the summer. As the irrigated land of the basin includes only a few thousand acres in the vicinity of Burbank, Pasco, Moses Lake, Winchester, and the Soap Lake section, the area of cultivated land closely approximates the acreage devoted to the production of small grain (largely wheat) by dry-farming methods.

TABLE 7.—*Approximate land area, land in farms, crop land, plowable pasture, and other farm land in the Columbia Basin area, Washington, in 1930* [1]

[All of Franklin and part of Adams, Grant, and Walla Walla Counties]

County	Approximate land area	Land in farms	Farm land		
			Crop land	Plowable pasture	Other farm land
	Acres	*Acres*	*Acres*	*Acres*	*Acres*
Franklin	771,840	553,547	238,538	26,250	288,759
Adams	776,213	596,626	504,356	19,637	72,033
Grant	1,287,910	423,279	166,247	17,024	240,008
Walla Walla	215,297	160,361	76,637	3,047	79,777
Total	3,051,260	1,733,813	985,778	66,858	681,177

[1] Estimated from data given in the Fifteenth Census of the United States, 1930.

NOTE: The land in farms represents 56.8 percent of the total area. Of the farm land, 56.9 percent is crop land, 3.8 percent plowable pasture, and 39.3 percent other farm land.

The adaptation of certain crops to certain soils has received practically no attention in the Columbia Basin area. The development of agriculture has been governed largely by the supply of moisture. In the dry-farming belt it is recognized that the more sandy soils are less productive than the soils of heavier texture, even in years of abundant rainfall, and that in years of scanty precipitation yields will not repay the cost of farm operation. The sandier soils are therefore regarded with less favor for grain farming, and large areas are not utilized. In the districts where irrigation water is available, either by pumping or by a gravity system, the cost of the water supply and not the soil condition will largely govern the amount of land to be brought under irrigation.

With the exception of the production of hay and small grains along Crab Creek west of Marlin, irrigation farming is limited almost exclusively to the production of fruit, alfalfa, and vegetables, with dairying and the production of honey as allied industries.

Both winter and spring wheats are grown. The acreages devoted to each are about equal, though the greater number of the farmers prefer, and are encouraged, to grow the winter varieties if weather conditions are favorable for sowing in the fall. Turkey and Triplet are the principal varieties of winter wheat, and a smaller acreage is devoted to Hybrid 128, Jones Winter Fife, and Ridit. Early Baart is the principal variety of spring wheat.

The average yields of wheat are not high, and this has led to the development of large operations in order to produce the crop as cheaply as possible. The average size of a farm in the dry-farming belt is about 640 acres. However, the average area farmed by one person is somewhat greater, as it is very common practice

for an owner of a section of land to rent adjacent land. It is not an uncommon sight to see one wheat field covering a square mile, and three or four contiguous sections (640 acres each) may be devoted entirely to wheat. No data are available as to the number of farms on which wheat is the sole crop, but the magnitude and importance of the wheat crop in the basin is shown by the production of 6,343,091 bushels in Adams, Franklin, and Grant Counties in 1929.

The yields of dry-farmed wheat vary with soil conditions, with the amount and distribution of rainfall, and with the thoroughness of tillage and fallowing operations. In the earlier days, attempts were made to utilize soils that, under normal rainfall conditions, were totally unsuited for the production of wheat by dry-farming methods, but such areas have been eliminated from the present wheat-growing area. The amount and distribution of the rainfall, assuming that proper tillage operations have been carried out, is the principal factor in determining the yield. No figures are available giving the acre yields of wheat, but they range from very small to as much as 30 bushels, or even more. The census figures for 1929 indicate an average yield of nearly 12 bushels an acre in Adams, Franklin, and Grant Counties.

Winter wheat is preferably sown after September 1, when moisture conditions are favorable. If the fall rains do not begin until October the farmers hesitate to sow winter wheat and may postpone sowing until spring. Spring wheat is usually sown as early as the land can be worked. Hoe drills are used for seeding on land that is free from weeds, and a disk drill on the weedy and brushy fields. The rate of seeding averages between 50 and 60 pounds an acre. A light drag harrow is used to cover the grain after seeding.

In the early days, smaller quantities of seed were commonly used (from 30 to 40 pounds an acre), and the practice of " volunteering " or " stubbling in " was also in common use. Volunteering was simply allowing a volunteer crop to grow and mature, and stubbling-in consisted in harrowing the stubble land sufficiently to cover the grain that was shattered during harvest. Present conditions of weed growth do not allow such practices.

Methods of cultivation differ somewhat according to the individual farmer, the character of the soil, the amount of labor necessary from year to year, and, to a large extent, the distribution of summer rains. All the wheat grown in the basin is produced under the fallow system; that is, a field is sown to wheat only in alternate years, and in the intervening season it is kept in clean cultivation to conserve moisture for the next season.

On the light-textured soils, which are subject to more or less blowing, the more successful farmers favor spring plowing, making a practice of sharing; that is, shallow plowing with plows having the end of the moldboard broken off; or, instead of plowing, they " rightlap "; that is, they set the left half of the disk harrow straight and the right half at an angle. In both methods the idea is to turn the soil partly over to a slight depth and at the same time to leave the trash as near the surface as possible and but partly covered, to aid in holding the surface soil in place.

The greater part of the sandy lands were taken up during the rush of settlement, about 1900, and the inability of the land to produce

profitable crops led to the abandonment of thousands of acres of this character. On many of the abandoned homesteads the soil drifted badly, and considerable damage has been done to adjacent lands. In time, the land became overgrown with Russian-thistle and tumblemustard, and various native plants slowly gained a foothold. Under such conditions the abandoned lands are no longer a menace, but it is inadvisable to attempt to place them under cultivation without irrigation.

In districts where the soil is not so easily affected by the wind, the better class of farmers prefer to plow to a depth of about 4 or 5 inches, either in the spring or fall. When the land is plowed in the spring, farmers prefer to plow as early as possible and to finish not later than May 15, as later plowing results in a loss of moisture from the soil. A 4- or 5-inch surface mulch is formed by the use of either a light harrow or some type of weeder. The harrow is used only when the field happens to be free from weeds, and the weeder performs the double duty of killing the weeds and maintaining the mulch. Ordinarily the fields are gone over twice during the summer, but the frequency of the operation is governed by the growth of the weeds, the most troublesome of which are Russian-thistle (*Salsola tragus*), tumblemustard (*Sisymbrium altissimum*), and pigweed. Where the weeds are scattered and the mulch is in good condition, removal of the weeds is commonly done with a hoe. At one time, the common practice was to burn the stubble, in order to destroy as many of the weeds as possible, but burning is now considered destructive to the organic matter in the soil, and this practice has been almost wholly abandoned.

Where weeding operations have not been effective, or where the heavier soils have developed a surface crust due to the beating action of rains, the fields are usually given a thorough harrowing before seeding to winter wheat. In spring planting the land must be harrowed to break the surface crust that has formed during the winter.

Within recent years smut has become a serious problem in the wheat fields. This trouble is more or less satisfactorily controlled by treatment of the seed. Formerly the seed was treated with a dilute solution of formaldehyde, but the use of dry copper carbonate has largely replaced the former method, and a number of machines are on the market for treating seed with that material. The dry treatment is not only easier to use, but it seems to be more effective in controlling smut.

Wheat harvest begins when the grain is well ripened, usually in July. Both combined harvesting machines and headers are used, and self-binders are used on the smaller or rougher farms. The combined harvesters, or combines, cut, thresh, sack the grain, and dump the sacks on the field. The sacks are commonly piled in the field or near the road and later hauled to the warehouses along the railroads. The headers remove only the heads of the standing grain. The heads are stacked at convenient places in the field, later threshed by steam- or gasoline-powered threshing outfits, and hauled to the warehouses. Shocked grain is either stacked and threshed later or is taken directly from the shocks to the threshing machines. The straw is either burned in the field, or a part of it is utilized to feed and bed livestock.

Other grains (oats, barley, rye, and corn) are grown to a small extent throughout the dry-farming area. The census data do not separate the acreages farmed under irrigation and those dry farmed, but practically all the wheat, oats, rye, and barley are produced under dry-farming methods and the greater part of the corn is grown under irrigation. As the yields of rye are much less than those of wheat and as the grain brings a smaller price, very little is grown in the better wheat-producing districts. It is largely produced in the section lying between the Wheat Belt and the areas of lowest rainfall. In favorable years yields range from 10 to 25 bushels an acre. Oats and barley do not yield sufficiently well to justify extensive plantings, but they are grown occasionally by a few farmers as feed for livestock. Cultural operations and harvesting of these grains are similar to those used in wheat farming.

Alfalfa is produced on practically every irrigated farm, regardless of the size, either as plantings between the orchard trees or in separate fields. When seeded in the orchards a nurse crop may be used, and in the larger plantings a nurse crop of small grain is commonly used. The greater part of the crop is consumed locally, although some is baled and sold. The average acre yield of alfalfa hay (when irrigated) for the entire area is about 3.5 tons, although yields ranging from 4 to 6 tons are occasionally obtained. In 1929, 578 acres were devoted to alfalfa in Adams County, 981 acres in Franklin County, and 2,705 acres in Grant County.

Small patches of potatoes and a few fruit trees are grown on some farms on the uplands without irrigation, but the yields are low and uncertain.

The largest fruit-farming district in the northern part of the area is in the vicinity of Moses Lake. More or less scattered orchards extend along Crab Creek from Marlin westward, and others have been developed in the vicinity of Soap Lake, Winchester, Ephrata, at Crescent Bar south of Trinidad, and along Crab Creek near Taunton. The aggregate area of these scattered orchards is probably about equal to the district in the vicinity of Moses Lake. In the southern part of the area a large acreage in the Pasco district is in fruit trees, a somewhat smaller area is around Burbank, and a few scattered orchards are along the river north of Ringold nearly to White Bluffs.

Apples are the principal orchard fruit, with pears, peaches, cherries, and plums and prunes following in the order named. Delicious, Jonathan, Winesap, Rome Beauty, and Stayman Winesap are the principal late varieties of apples, and the early varieties are Fameuse (Snow), Yellow Transparent, Winter Banana, Jefferis, and Bietigheimer. The fruit is sold largely on eastern markets.

Both clean-cultivation and cover-crop methods of orcharding are followed, the method being governed almost entirely by the amount of water available for irrigation. Where the water supply is abundant a cover crop of alfalfa is usually maintained throughout the year, and where it is limited clean cultivation is the rule.

Peaches are grown alone in orchards, as fillers in young apple orchards, or as occasional trees around the farmhouses. Only a few orchards are devoted wholly to prunes or plums, but the greater numbers of these trees occur as small plantings in the vicinity of the

farm lots. Small fruits and vegetables are receiving some attention, particularly in the Pasco district, strawberries, peas, asparagus, melons, and onions being the most important truck crops. The climate in this part of the basin enables the grower to put these crops on the market ahead of those of most of the other producing sections of the Northwest, and the returns are usually very satisfactory. Berries are grown either in patches or between rows of young fruit trees. Vegetables are usually planted alone.

Small plantings of grapes are found throughout the irrigated districts, but the total acreage is small. Yields are generally good, and there is a ready market for the fruit. Concord, Worden, and Muscat are the principal varieties of grapes grown.

Areas not suitable for cultivated crops, in addition to large tracts of abandoned homesteads, are utilized as grazing land for cattle, horses, and sheep. As the raising of horses is not so profitable as when the country was an open range, these animals are not raised in such large numbers as formerly. Some cattle range on the grazing lands within the area throughout the year, but many are driven to the mountains during the summer and are brought back for winter grazing. Sheep are commonly grazed in the area until about the middle of May and are then taken to the mountains for the summer. Most of the sheep are grazed in the eastern and southern parts of the area, and the cattle in the western part.

Dairying is practiced to some extent in both the dry-farming and irrigated districts, but the dairy products do not meet the needs of the local population. On the dry-land farms dairying is a side line, and the difficulty of procuring feed is a large factor in limiting the number of cows that can be carried. Many farmers sow rye along the roads and graze their cows on it during the spring. By the time the rye is gone, the Russian-thistle has developed and is used for pasture until fall. During the winter the cows are fed straw, chaff, grain hay, and occasionally some grain. In a few localities saltgrass in the coulee or creek bottoms furnishes good summer pasture.

On only a few of the irrigated farms is dairying an exclusive branch of farming. The number of cows kept on the irrigated farms ranges from 1, to supply the family table, to herds of 15 or 20. Milk is either disposed of in the nearest town, or the cream is separated and shipped to creameries in Spokane or Seattle.

Climatic conditions within the Columbia Basin area do not allow diversification of crops, without irrigation, and it is extremely difficult for the dry-land farmer to establish any system that will maintain the fertility of the soil. It is a well-known fact that continuous production of a crop without proper return of plant food to the soil will ultimately result in such low yields that farming operations will become unprofitable. Since the leading farmers have ceased burning their grain stubble, a small amount of organic matter is returned to the soil by plowing under that material. Some of the farmers are using as much straw as possible in the care of livestock and returning the manure to the land. Any easy and cheap system that can be devised to maintain the yields of grain will be welcomed by farmers of this area.

Commercial fertilizers have, as yet, played little part in the agriculture of the area. In the irrigated areas some commercial

fertilizers are used to a small extent in the orchards and on the truck crops. All the available manure is used, but most of the farmers depend on the alfalfa grown in the orchards for a supply of organic matter. As agricultural conditions under irrigation become more settled and the needs of the soils and crops are better understood, a more systematic and extensive use of both manures and commercial fertilizers will undoubtedly be developed.

Plowing is usually done with 2- or 3-bottom moldboard plows drawn by horses or mules. Tractors have been tried rather extensively, and, although a few are in use on some of the larger ranches, horses or mules are still preferred by the larger number of farmers. As a general rule, 1 man with 8 horses can handle three quarters of a section (480 acres), or about 240 acres each of wheat and fallow. A farmer handling 1,000 or more acres commonly keeps about 45 head of work animals. During the winter the animals are usually fed chaff, straw from headed grain, wheat straw, or straw with a little grain hay, and during the working season they are fed chaff and grain, baled hay, or hay and grain.

In the dry-farming districts farming on shares is common practice, the land being leased for one fifth or one fourth of the crop delivered to the warehouse. Much of the land is leased for a term of years on the customary basis of one third of the crop to the owner. Very little land is rented for cash. The irrigated farms are largely operated by the owners.

The demand for farm labor is very irregular but is heaviest during plowing and harvesting periods. On many of the irrigated farms the owner performs the greater part of the labor, except during fruit-picking and alfalfa-cutting seasons.

Land values range widely, depending on location, improvements, type of soil, and water supply.

IRRIGATION, DRAINAGE, AND ALKALI

The history of the development of irrigation farming within the Columbia Basin area is similar to that of the dry-farming industry—that is, very little development for a long time, a rather rapid growth that led to irrigation in unsuitable localities, a decline in the irrigated area, and finally little change in the irrigated area. The rush to develop irrigated tracts occurred along the larger streams, wherever there were areas of bottom land, and an attempt was made to irrigate land in the western part of Franklin County by gravity diversion of water from Columbia River near the head of Taylor Flat. Developments were also begun on large areas in the Moses Lake, Winchester, and Soap Lake districts, where water was obtained by pumping from wells. Many of these attempts resulted in failure, which was in most cases owing to the cost of pumping.

Irrigation is now practiced along all the rivers in the area except the Palouse and Touchet, along some of the larger coulees, and on the more level land in the vicinity of Quincy, Winchester, Ephrata, Soap Lake, and Moses Lake.

Irrigation in the area was begun by a few of the earlier settlers, who diverted the flood waters from the coulees to increase the yield of native hay. The uncertainty of the floods and the small acreage

that could be served by such diversions rendered this form of irrigation of little importance, and the practice has become practically obsolete. Apparently the first attempt to use the water in the rivers for the irrigation of adjacent land was made early in 1901, when a large wheel, which was turned by the current of the stream, was installed at the foot of Five Mile Rapid and used to lift water onto the lower lands. The first gravity diversion of water seems to have been effected about 1905 by a small canal which carried water from Walla Walla River onto lands in the vicinity of Wallula.

As practically all the rivers in the area lie much lower than the adjacent land, local systems of gravity diversion are not practical, at least within reasonable cost, and irrigation by pumping from the nearby streams has become the means of carrying water to the land. In the northern part of the area, irrigation is effected by pumping from underground water. Gasoline engines were first used as a source of power for pumping, but in later years electric power has become generally available throughout the basin.

Aside from the economic conditions which will govern the future extension of the irrigated area, the development of irrigation within this area depends on obtaining an adequate supply of irrigation water at a reasonable cost and on the expense of preparing the land for irrigation. The favorable results that have followed the irrigation of small bodies of land remove any doubt as to its productivity. The supply of water in Columbia and Snake Rivers is ample for the irrigation of all the irrigable lands within the area, but these rivers flow in valleys many hundreds of feet below the level of the uplands. Various schemes have been proposed, from time to time, for the irrigation of parts of the area, but within the last few years a comprehensive plan has been developed for the irrigation of practically all the area either by a gravity diversion of the waters of Clarks Fork River at a point near the town of Newport, Wash., about 60 miles north of Spokane, or by the use of the Grand Coulee as a storage reservoir for water from Columbia River. At the present time the latter plan is favored.

The most extensive tracts of irrigated land within the area are west of Pasco, adjacent to the northern bank of Columbia River, the lower-lying land in the western part of Walla Walla County, and lands in the vicinity of Moses Lake. A small area of irrigated land lies in the river bottoms south of Trinidad, a number of irrigated farms are in the district between White Bluffs Ferry and Ringold, and a few irrigated tracts are along Crab Creek between Corfu and Taunton. The latter are irrigated by a gravity diversion of the waters of the creek, but the rest of the areas mentioned are irrigated by means of pumps.

The wind movement will not be a generally serious factor under irrigation. Throughout the greater part of the irrigable lands the soils would be more stable under irrigation than under dry-farming conditions, owing to the increased amount of moisture and to the fact that a large part of the land would undoubtedly be continually in crops. The heavy winds readily transport the lighter-textured soils whenever the protective covering of natural vegetation is removed, and the real danger to the soil lies in the future clearing of such lands by settlers and its subsequent abandonment. The adjoin-

ing farms would suffer from the moving soil and the value of much of the land would be destroyed, owing to the overburden of wind-blown materials.

A part of the depression now occupied by the channel of Crab Creek, between the towns of Marlin and Wilsoncreek, was formerly occupied by a shallow marshy lake that was maintained by an obstruction in the channel of the creek. The obstruction, near the town of Wilsoncreek, was removed in 1904, the land drained, the tule growth removed, and the area sown to small grains. At the present time, the flow of Crab Creek is carried by a small channel that acts both as a drain and as a means of supplying water to the subsoil. When the creek is high, the water table is near enough to the surface to supply the crops with water. When the flow of the creek is small and the water lies at too great a depth for the roots of the crops, the gates in the channel are closed until the water table has risen and moistened the subsoil.

The soils in the agricultural districts of the area are remarkably free from alkali, which is found only in a few restricted localities along some of the larger coulee bottoms, the most noticeable occurrence being in the Crab Creek bottoms between Corfu and Taunton, where irrigation of some of the bottom lands has resulted in an accumulation of alkali salts in the soil to such an extent that crop production is becoming seriously affected. In this locality alkali-trouble has developed both because the water used carries a noticeable amount of dissolved salts and also because local drainage conditions are unfavorable.

SOILS

In the general discussion of the soil relations in a large area, we are not concerned primarily with the historical geology of the region or with the geological processes by which the various formations were developed, except so far as those processes have determined differences in texture of the soil material or of that part of the geological material from which the soils were developed. We are, however, concerned with the lithology of the region, or with the lithological character of the materials, and more intimately concerned with them where the soils have developed from unconsolidated material.

In the Columbia Basin area the soils have developed almost entirely from unconsolidated material which lies on consolidated rocks. Areas in which the rocks appear on the surface have been mapped, not as soil, but as scab land which is essentially rock outcrop.

The area is underlain throughout by basalt which consists of a series of successive lava flows lying, in most places, nearly horizontal. The unconsolidated materials referred to cover the basalt in all places except in the areas of scab land.

The unconsolidated materials are of three kinds, according to process of accumulation, whether wind-blown, glacial, or sedimentary material. Wind-blown materials may be fine grained or comparatively coarse grained, consisting of loess or silty material and sands, some of which are dune sands. The glacial material is mainly coarse grained (gravel and sand), though in a few localities the soil

material is finer. The sedimentary materials are generally fine grained, consisting of calcareous silt, clay, and fine sand.

In general each of these materials occupies a particular part of the area. In the eastern part, the bedrock is covered by silty loess deposits. The western boundary line of the silty deposits runs in a general northward direction from Snake River at a point about 20 miles northeast of Pasco, northwestward to Eltopia on the Northern Pacific Railway, and thence in a general northward direction, passing a short distance west of Othello and Wheeler to the boundary of the area a short distance northeast of Adrian in Grant County.

The glacial material occupies the north-central part of the area, extending southward from the vicinity of Adrian and Ephrata. It consists mainly of water-laid deposits—gravel in the northern part, sand and loamy gravel farther south, and sandy deposits in a belt extending east and west across the central part of Grant County. In places the sandy materials have been shifted by the wind, in their present position being essentially wind-blown materials. The gravel deposits farther north are in places covered by sand blown from this region. It is well within the range of possibility that some of the sand was not derived from glacial material but was brought down by the rivers.

The sedimentary materials occur mainly in the western and northwestern parts of Franklin County and in some places in the southern part of the area. The southern part of Franklin County is made up largely of sandy material which has been very much shifted by the wind. Most of it was accumulated in its present position by the wind.

It is on these materials that the soils of the area have developed. The region is one in which the dynamic processes of soil development have been almost entirely free from local influences of parent material, relief, or poor drainage, which disturb and delay normal soil development. The two most important environmental factors which have determined the characteristics of the soils of the region, aside from the texture of the soils and such changes of texture in the soil profile as have been brought about by changes in conditions of deposition during the time when the material was being accumulated, are those of climate, especially rainfall, and natural vegetation.

The Columbia Basin area is a part of a large region having a characteristic gradation in climatic and vegetational conditions. This region extends from the humid timber-covered more or less mountainous parts of the extreme eastern part of the State and adjacent parts of Idaho westward to the region of the same general character beginning at Columbia River. The northern boundary of this region is formed, approximately, by Columbia and Spokane Rivers, and the southern boundary extends well up the slopes of the Blue Mountains in the northern part of Oregon. The region is treeless, comparatively smooth, grass or brush covered originally, and characterized by a subhumid climate in the east, a gradually drier climate westward, and a very dry climate in the western third of the region. The Columbia Basin area occupies the western half of this region and, therefore, the drier part. The rainfall is low and the natural vegetation consisted, until the land was placed in cultivation, of a rather sparse growth of grasses in the eastern part and of desert shrubs in the western part.

The mean annual temperature is about 50° F. The winters are rather cold and the summers hot. The temperature throughout the area, except so far as it is locally affected by differences in rainfall, is uniform and has not been an important factor in the determination of such soil differences as exist within the area. The rainfall in the western part is less than 10 inches, and in the extreme eastern part slightly more than 15 inches. A rather sparse cover of grass originally spread over that part where the soils have developed from wind-blown silts, and the rest was covered by desert brush. The darker colored soils, therefore, occupy the eastern part and the lighter colored soils the western part. All the soils contain lime carbonate in some part of the soil profile. In the eastern part the lime carbonate occurs only in the subsoil, nowhere, except in unimportant local areas, at a depth exceeding 3 feet, and in the western part it may be present in the surface soil.

The surface relief is essentially that of the Great Plains in miniature. The area consists, like the Great Plains east of the Rocky Mountains, of a smooth country in which the rainfall decreases westward and in which, therefore, the cover of natural grass vegetation decreases in density in the same direction. The Columbia Basin area, however, extends westward into a climatic zone that does not exist in the main part of the Great Plains area, as the latter area is abruptly terminated by the Rocky Mountains before the rainfall has become so low as to prevent the growth of grass and to promote the growth of a brush vegetation. The Columbia Basin area, therefore, constitutes a more complete gradation from a humid timber-covered region to a desert region than that occurring in the central part of the United States extending from the humid timberlands of eastern Minnesota westward to the Rocky Mountains. In the Columbia Basin area the changes from east to west are much more rapid than in the Great Plains area.

The soils of the area may be placed in three groups—dark-brown, brown, and gray soils. The dark-brown soils occupy the extreme eastern part, the brown soils the east-central part, and the gray soils the western part. The western boundary of the brown soils coincides essentially with the western boundary of the silty wind-blown material, or loess. The gray soils occupy the areas of comparatively coarse material in the western part of the area and support a brush vegetation.

It will be noted that two of these groups lie within the loess region. The boundary line between these two groups, or between the dark-brown and brown soils, extends from the southern boundary of the smooth upland plateau lying about 15 or 20 miles northeast of Pasco, slightly northeastward, parallel to Snake River and 10 or 15 miles west of it, to the latitude of Kahlotus, and thence northeastward, passing a few miles east of Lind and across the northern boundary of the area north of Lind.

The whole area of dark-brown soils is shown on the map accompanying this report as Ritzville loams which include some very fine sandy loams and possibly some sandy loams. The profile is normally but faintly developed. The loose surface layer is a few inches thick and in many places is calcareous, owing to the apparent recent deposition of the material which has come from farther west and is, therefore, fresh material that has not yet been leached of its

carbonates. It is lighter in color than the underlying material and shows definite lamination, which is apparently the result of wind stratification rather than of soil development. Immediately beneath this layer the material is somewhat more firm but it is nowhere so firm or compact as the corresponding layer in the dark-brown soils of the Great Plains east of the Rocky Mountains. This is partly because of the youth of the soil, apparently, but to a greater extent is due, probably, to the composition of the material. None of the soils in the area seems to be influenced to a perceptible extent by an accumulation of salts which cause the development of heavy subsoil layers. The subsoil is dark brown, and it contains a higher percentage of organic matter than any other layer of the soil. It extends to a depth of 12 or 15 inches, below which the material becomes somewhat looser and lighter colored, and at various depths, but in most places less than 30 inches, contains lime carbonate.

The brown soils in the western part of the loessial area have a profile similar to that of the dark-brown soils, but all the features are less definitely expressed, except that of the layer containing lime carbonate. The color is pale brown with a gray tint, and the line of demarcation between the thin loose surface layer and the slightly more campact underlying layer, which extends to a depth of less than 12 inches, is not so well defined as in the dark-brown soils. In the extreme western part of the area the latter layer is scarcely noticeable. This may be caused by the continual shifting of the soil material by the wind. The lime-carbonate layer lies at a depth of about 2 feet, and the surface soil effervesces in acid over a larger part of its area than in bodies of the dark-brown soils. These soils are shown on the map as Wheeler loams. They include slightly coarser materials than the silt loam, but the prevailing soil is the silt loam. Both the dark-brown and the brown soils in the Columbia Basin area belong to the lighter members of these two groups as generally defined by soil scientists.

The greater number of the soils of the Columbia Basin area belong in the gray desert soil group and have been developed from parent materials other than silty materials. These have been differentiated in mapping according to the processes by which the parent materials were accumulated. One of the groups includes the sandy wind-blown soils comprising members of the Quincy, Winchester, and Koehler series. A second group includes soils which have been derived from sedimentary materials and includes members of the Sagemoor, Ephrata, Warden, and Burke series. Some of these soils, such as the Ephrata and Warden, have been derived from the gravelly and sandy outwash deposits in the northern part of the area. The Sagemoor soils have been derived from the sedimentary deposits, seemingly older than the glacial deposits, lying mainly in the western part of Franklin County. The rest of the soils are alluvial soils and are grouped in a number of series, the Ringold, Pasco, Beverly, Esquatzel, Washtucna, Naylor, and Red Rock. Muck and peat, dune sand, rough broken and stony land, and scab land are miscellaneous units mapped.

All the soils of the gray soil group, except the alluvial soils, have imperfectly developed soil profiles, their differentiation being based on differences of parent material. Considered on the basis of funda-

mental soil characteristics they are essentially identical, but they differ one from the other in texture and in such details of characteristics as are dependent on the slightly different characteristics of the parent material. Practically all of them are coarse textured, and this has seemingly prevented the development of a well-defined desert soil profile. In the heavier members of the Sagemoor series and in the Ephrata sandy loams, there is a faint development of the desert profile, showing a loose gray surface layer, a faintly developed very thin layer of pale-brown material lying immediately beneath this, and an underlying lighter-colored material which is calcareous at a very slight depth beneath the surface. Owing to much shifting of soil materials by the wind, the desert profile is well defined in the topmost few inches only.

A brief description of the soil series occurring in the Columbia Basin area follows:

The soils of the Ritzville series are characterized by medium dark brown friable surface soils overlying slightly lighter colored subsoils. When wet the surface soils appear darker brown. The soils of this series are free from gravel. The surface soils are noncalcareous, but the subsoils are calcareous below a depth of 30 inches. The subsoils may be sufficiently compact to enable them to stand in newly cut banks, and the substrata may or may not be noticeably compacted and cemented. An imperfectly developed columnar structure may be seen in places, but well-defined solonetz spots are absent or are of very rare occurrence.

The Wheeler soils have developed from the same kind of parent materials, accumulated in the same way and presumably from the same sources as the soils from which the Ritzville soils developed. The relief is also the same, but the annual rainfall is lower, and the cover of grass is thinner. Therefore the soils are strikingly lighter colored and somewhat less leached than the Ritzville soils.

The soils of the Winchester series range from dark gray to black in color. They consist of a pepper-and-salt mixture of dark-colored basaltic sand and light-colored particles of quartz. The dark-colored basaltic sand predominates and gives the characteristic dark color to the soils. In most places the texture is uniform to a depth of 6 feet, and only along the boundaries between soils of this and of other series are the soil materials stratified above that depth. Lime is leached from the surface soils but is commonly present at a depth of about 40 inches.

In the aggregate, the soils of this series cover large areas, but the extent of the individual types is in many places limited to small scattered bodies with poorly defined boundaries, and for the purpose of this reconnaissance survey the soils have been designated simply as sands. In the southern part of the area, the sands occur as small knolls and ridges of very small extent, occurring among more extensive areas of soils of the Ephrata series in which the individual bodies of Winchester soils are too small to be of sufficient importance to justify the work necessary to differentiate them on the map. Under such conditions the soils of the two series have been shown on the map as soils of the Winchester and Ephrata series, undifferentiated.

The surface soils of the types of the Ephrata series are predominantly brown or light brown. Some areas present a dark-brown or light yellowish-brown color. More or less water-worn gravel and cobbles are present in the surface soil. The subsoils are similar in color to the surface soils, or are slightly grayer, depending on the amount of lime present. A substratum of water-worn cobbles, gravel, and boulders, with considerable interstitial sand, but typically of loose porous character, occurs at a depth ranging from 20 to 60 inches. The gravel substratum rests on bedrock, which lies at different depths. The subsoil in many places contains gray lime accumulations, and the gravel in the upper part of the gravelly substratum is lime coated.

The soils of this series are derived mainly from stream-laid materials, though in places the surface soils probably include some admixture of wind-laid materials. In the northern part of the area the development of these soils is closely related to the period when glaciers occupied areas to the north and when outwash streams, associated with the glacial drainage, were depositing extensive masses of cobbles, gravel, and finer materials. Such materials were very largely derived from basaltic materials, although some is from granitic sources. In the western part of the area, from Saddle Mountains southward, the development of the soils of this series was more closely associated with the activities of the larger streams, and although the greater mass of the soils is made up of basaltic material, in places rather large quantities of material are derived from granitic rocks. This characteristic is most evident in the area of these soils that occupies an extensive terrace south of the western end of Saddle Mountains, where the proportion of lighter-colored rocks and gravel is large, giving rise to lighter-colored material than is characteristic of the normal subsoils.

The Quincy series is characterized by light-textured incoherent porous light-brown soils which occupy ridged and dunelike positions. In most places the texture, structure, and color of these soils are consistent to a depth of 6 feet. In many places where these soils merge with soils of other series, the subsoils are finer textured, lighter colored, and more compact. The substrata of the Quincy soils consist mainly of stratified, compacted, and calcareous materials similar to the formations exposed in the White Bluffs. In a few places the substrata may consist of loessial deposits or of stratified sand and gravel, over which the wind-laid Quincy materials have been superimposed.

The soils of this series are of aeolian origin, having apparently been blown largely from the sandy bars along the channel of Columbia River. These soils are differentiated from the soils of the Winchester series, which are similar in mode of accumulation, by the absence of basaltic material and by the stratified compacted calcareous substrata of finer texture, in place of the stratified sand and gravel.

The soils of the Koehler series are characterized by light grayish-brown or light-brown surface soils and by subsoils of somewhat lighter tints. These are directly underlain by substrata consisting of dense hard white limestone and these, in turn, by compacted strata of fine sand and silt. The surface soils and subsoils are derived from old stream-deposited sediments that have been reworked and redistributed by the wind or which have been covered by wind-blown materials. The substrata of stratified and compacted sediments are of

water-laid formation and are comparable to the strata that are exposed along the White Bluffs. The surface soils in places carry some fine water-worn gravel of mixed origin, and fragments of limestone or very dense hardpanlike material are present in a few places in the subsoil. Both the surface soils and subsoils are calcareous in spots, but the materials making up the greater part of these horizons are noncalcareous.

The soils of the Burke series have light grayish-brown surface soils underlain by subsoils of similar texture, although usually of slightly lighter color, resting on a layer of hard white limestonelike material which, in turn, is underlain by compacted strata of fine sand and silt. The average depth to the limestone is about 4 feet below the surface. Over the greater part of the area occupied by the soils of this series the limestone is hard and massive, but in places rather extensive areas occur in which it is somewhat shaly and more or less fractured into irregular blocks.

The surface soils are typically leached of lime and are noncalcareous, with the exception of included particles and fragments of the underlying calcareous materials which may have been intermingled with the surface soils by burrowing animals or other agencies. The subsoils are slightly compacted, in many places exhibit a columnar structure, and a layer of lime accumulation occurs in most places at a depth ranging from 20 to 30 inches. In previous surveys in this region the limestone material has been regarded as of secondary "hardpan" development.

Small water-worn gravel and more or less water-worn fragments of limestone occur throughout the soil mass above the limestone, and in places a thin bed or layer of water-worn limestone gravel lies directly above that formation. The substratum of the soils of this series is identical with that underlying the soils of the Koehler series, and the soils of the two series are differentiated according to the manner in which the surface soils have been affected by the winds.

As mapped, the series includes the soils which were classified in the older detailed survey of the Quincy area [3] as hardpan phases of the Quincy soils. They are recognized in the later survey as representing a distinct series of soils to which the name Burke has been given.

The Sagemoor series includes soils having light-brown or grayish-brown surface soils overlying lighter-gray subsoils. When moist the color of the surface soil is more pronounced brown than it is under dry field conditions. The soils of this series have weathered from finely laminated fine sand, silt, and clay that were deposited in and around the margins of former lakes. It is recognized, however, that later stream-distributed and wind-borne materials have also entered into the soil formation. These underlying stratified sediments are both siliceous and calcareous and in most places are firmly cemented or compacted. The surface soils are in places slightly calcareous, and the subsoils are almost invariably so.

The soils of the Sagemoor series occur in lower positions than those of the Burke and Koehler series, owing to the removal of the limestone and underlying sediments by stream erosion. They differ

[3] MANGUM, A. W., VAN DUYNE, C., and WESTOVER, H. L. SOIL SURVEY OF THE QUINCY AREA, WASHINGTON. U.S.Dept.Agr., Bur. Soils. Field Oper. 1911, Rept. 13: 2227–2286, illus. 1914.

from the Burke soils in the absence of the firm limestonelike layer in the subsoils. The color of the surface soils is almost identical with that of the Ritzville soils. The Sagemoor soils are differentiated from the Ritzville soils in that the Sagemoor soils are derived from weathered compacted strata.

The soils of the Warden series are characterized by light grayish-brown or light-brown predominantly light-textured noncalcareous surface soils overlying, at a depth ranging from 36 to 48 inches, slightly lighter brown subsoils which are more compact, slightly heavier textured, and calcareous. These soils contain some water-worn gravel but are without pronounced beds of stratified gravel within a depth of 6 feet. These soils are of mixed origin and have been derived from somewhat weathered old stream-laid deposits. The finer-textured subsoils differentiate these soils from soils of the Ephrata series, which have porous gravelly subsoils at a slight depth. In texture, color, and structure the surface soils of the Warden soils in many places closely approach those of the Ritzville soils, and soils of the two series intergrade without a distinct line of demarcation.

Soils of the Ringold series are characterized by light-gray or yellowish-gray surface soils containing some spots of brownish gray or light grayish brown. The subsoils are of the same color as the surface soils, and they have become slightly compacted or altered since deposition. The underlying materials consist of either compact stratified fine sand and silt, identical with those exposed in the White Bluffs, or of less compacted water-laid sediments that form a part of the stream-terrace materials of the area. Along Columbia River, the underlying material is composed of stratified sediments, and in most other bodies it is similar to that underlying the Warden and Esquatzel soils. Both surface soils and subsoils are highly calcareous, the lime being uniformly distributed through the soil profile, without the formation of concretions or of layers of pronounced lime accumulation or cementation. The soils of this series occupy local alluvial fans or foot slopes and have been derived from materials washed out from the consolidated strata that are exposed along the White Bluffs and deposited in their present position. Some undifferentiated materials, which have been eroded from the light-textured and uncompacted surface soils overlying the White Bluffs formation, are included in mapping.

The soils of the Esquatzel series are characterized by light-brown or light grayish-brown slightly compact surface soils that are typically underlain, to a depth of 6 feet or more, by subsoils of similar color and structure. In many places, both surface soils and subsoils are stratified with gray or nearly white very fine sand and silt, and gravel occurs throughout the soil profile. A gravelly substratum resting on bedrock is present in places at a depth of 4 feet or more below the surface, and locally bedrock occurs within a depth of 6 feet. The surface soils are noncalcareous, and the subsoils contain slight mottlings of lime accumulation. The larger part of the material forming the surface soils and subsoils has been derived from the surface soils of the Ritzville soils, through erosion. The substrata, and in places the deeper parts of the subsoils, consist of water-worn basaltic gravel, comparable with those forming the

subsoils of the Ephrata soils. The Esquatzel soils occupy the bottoms of coulees and local drainage ways.

The surface soils of the Washtucna soils are light grayish brown or light brownish gray. They are underlain by lighter brown or more yellowish brown subsoils. Both surface soils and subsoils are calcareous or intermittently so. Both are very uniform in texture, and the subsoils are moderately compact. In most places the substratum is composed of material similar to the overlying layers. A deposit of gravel or the occurrence of bedrock within a depth of 6 feet from the surface is very rare. The surface relief is practically level, and the soils are developed in low areas. The soil materials are largely derived from materials eroded from adjacent higher-lying land, and some wind-blown material has been contributed. In several localities the soils of this and of the Esquatzel series were so intimately associated as to preclude the possibility of separation in a reconnaissance survey.

The Pasco series embraces dark-brown or dark grayish-brown recent-alluvial soils which are underlain by a porous gravelly substratum at a depth ranging from 6 to 15 feet. In most places the subsoils are somewhat lighter colored than the surface soils. The parent materials are derived from a variety of rocks and include both basaltic and granitic materials.

The soils of this series occur mainly in the alluvial bottom lands bordering the larger streams and are overflowed occasionally. The surface soils are noncalcareous, and the subsoils in few places contain appreciable quantities of lime. The soils of the Pasco series differ from the soils of the Beverly series, with which they are closely associated, in their darker color, also in the greater depth at which the gravelly substratum lies. In the present reconnaissance survey, the soils of the Pasco and Beverly series have not been differentiated.

In an earlier soil survey [4] covering a part of the Columbia Basin area, soils of two series were recognized as being of recent-alluvial origin and occurring in scattered bodies along a number of the larger coulee bottoms. These were the Naylor and Red Rock soils. Recent field work indicates that these soils have a number of characteristics in common, such as origin, source of parent material, color, drainage, and crop adaptation, and also that in many places they occur as small intermingled bodies that could be separated only in a very detailed survey. Because of this, it was not considered advisable to attempt the separation of the numerous small areas, and they are shown on the soil map as undifferentiated Naylor and Red Rock soils.

The details of the characteristics of the soils of the area are described in succeeding pages and need not be further discussed here. The accompanying soil map shows their location and distribution in the area, and table 8 gives their acreage and proportionate extent.

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[4] See footnote 3, p. 25.

TABLE 8.—*Acreage and proportionate extent of soils mapped in the Columbia Basin area, Washington*

Type of soil	Acres	Per cent	Type of soil	Acres	Per cent
Ritzville loams	265,408	8.7	Warden sandy loams	129,216	4.2
Hardpan phase	704		Warden silt loam	11,648	.4
Wheeler loams	708,736	23.1	Ringold clay loam	3,392	.1
Hardpan phase	1,280		Esquatzel very fine sandy loam	46,400	1.7
Winchester sands	135,040	4.4	Dark-colored phase	5,376	
Winchester and Ephrata sands and sandy loams, undifferentiated	75,904	2.5	Washtucna very fine sandy loam	7,040	.2
Ephrata sands	52,672	1.7	Washtucna and Esquatzel loams, undifferentiated	9,600	.3
Ephrata stony sandy loams	126,848	4.1	Beverly and Pasco sands and sandy loams, undifferentiated	23,680	.8
Ephrata sandy loams	368,128	11.9	Naylor and Red Rock soils, undifferentiated	18,176	.6
Quincy sands	129,472	4.2	Muck and peat	3,584	.1
Quincy and Sagemoor sands and sandy loams, undifferentiated	66,368	2.1	Dune sand	43,392	1.4
Sagemoor sandy loams	103,360	3.3	Rough broken and stony land	93,120	3.0
Koehler sands	48,064	1.5	Scab land	353,472	11.5
Burke sands	58,112	1.9			
Burke sandy loams	179,776	5.8	Total	3,084,160	------
Burke and Ephrata fine sandy loams, undifferentiated	16,192	.5			

RITZVILLE LOAMS

This group of soils includes the undifferentiated fine sandy loam, very fine sandy loam, and silt loam members of the Ritzville series. Of these the silt loam predominates and is the most important.

The surface soils of the Ritzville loams are predominantly dark brown, the color gradually becoming darker from west to east. This change corresponds to a somewhat more luxuriant grass growth eastward because of an increasing rainfall in this direction. When wet, the surface soils have a pronounced brown tint, and the subsoils are light grayish brown. The surface soils are noncalcareous throughout. Free lime occurs at different depths below 30 inches, the amount of lime in the subsoil generally increasing with depth, and the material may become somewhat indurated, giving rise to well-compacted and cemented layers (pl. 1, *A* and *B*). North of Lind Coulee, the substrata are commonly strongly calcareous and cemented, and they contain numerous thin plates and threads of white lime deposits. This material in few places is within 6 feet of the surface on the more level areas of the soil, but on the slopes leading down toward local drainage channels, where erosion has removed some of the surface soil, the compacted stratum may be within 3 feet of the surface and may be seen as narrow white outcrops near the bases of slopes. These partly cemented layers absorb water slowly but are usually permeable to the roots of the native plants. Except on some of the lower slopes, they are not close enough to the surface to affect the water-holding capacity of the soils under normal rainfall conditions, but under irrigation they would be a very prominent factor in preventing the downward movement of excess subsoil water.

The Ritzville soils cover an important part of the area of the Columbia Basin soil-survey project. With the exception of narrow bodies along the channels of some of the larger coulees, they occupy an unbroken body stretching along the southeastern part of the area. These soils differ from the Wheeler soils in that they have a darker color and a somewhat better developed profile. There is no sharp

or well-defined difference between the two groups of soils, the Ritzville being the eastern rather dark brown soils of the plains region covered by the map, and the Wheeler, the western light-brown soils of this same plain. The Ritzville soils become lighter colored westward and imperceptibly grade into the Wheeler soils. As the change in color is gradual the line of demarcation cannot of course mean that any sudden change takes place along its course. It merely signifies that the soils east of it are, in general, darker in color than those west of it.

The relief of the areas occupied by the Ritzville soils ranges from that of very uniform plains to that of badly eroded ridges and hills. In Franklin County, erosion by the local coulees has developed a series of very narrow topped ridges bounded by steep slopes. The Ritzville soils lie at somewhat greater elevations than other soils in the area, as they stretch across the eastern part.

Surface drainage is well established throughout these soils, as deeply cut coulees occur in practically every section of land. These drainage courses are ample to carry the excess waters from ordinary storms within their watersheds. The soils absorb and retain the rainfall of all but the most severe storms. This is characteristic of soils of this character wherever they occur, and it is this condition that makes it possible to produce profitable crops of grain without irrigation in regions of low rainfall.

The natural vegetation consists of grass, with an increasing amount of sagebrush and rabbitbrush westward.

In their virgin condition these soils are well supplied with the mineral elements necessary for plant growth, but their organic-matter content is moderately low. Under the methods used in the continual 1-crop system there is practically no return of plant food to the soils, and they are beginning to show a somewhat lessened productivity. Wheat yields from 10 to 40 bushels an acre, depending on the seasonal rainfall, the cultivation, and the texture of the soil. On the areas of lighter-textured Ritzville soils yields of wheat are not so satisfactory as on the less sandy soils, and the prevailing practice is to devote the sandier soils to the production of rye. The average yield of rye is less than that of wheat, but the greater certainty of obtaining a stand of rye makes the production of this grain desirable.

Land prices vary, depending on improvements. Under irrigation these soils would be excellently adapted to all crops suited to local climatic conditions. The area which might be irrigated would depend largely on topographic conditions. The more uniform areas could all be easily placed under irrigation, but with increase in the degree of slope or roughness of the surface the crop range would become more limited, both because crops could not be well produced on the steeper slopes and because of the increased cost of irrigation of such areas.

A small area of Ritzville silt loam having an indurated subsoil lies about 7½ miles north of Washtucna, in the midst of a large area of Ephrata sandy loams.

As mapped in this area, these soils include some undifferentiated materials of somewhat higher organic-matter content and of darker dull grayish-brown color than are typical of soils of the Ritzville series. The zone of lime accumulation in these variations is also

somewhat deeper, and in a few localities no pronounced accumulation of lime occurs within a depth of 6 feet. The included soils approach in color and profile the soils of the related Palouse series which are of wide occurrence in the more elevated region to the east, where the rainfall is higher.

Ritzville loams, hardpan phase.—In one locality, the cemented subsoils of the Ritzville soils approach within less than 6 feet of the surface, and the soil has been separated as a hardpan phase of the Ritzville loams. This area lies 4 miles northeast of Ralston.

WHEELER LOAMS

The Wheeler loams are brownish gray, the brown tint being caused by oxidation masked by a small percentage of organic matter. The soil profile in all other respects than that of color of the surface soil, is essentially like that of the Ritzville loams. Such differences as occur are those of degree rather than of kind. The firmness or density of the soil from the surface to a depth of several feet is practically uniform, the slightly firm cloddy layer, which in the Ritzville soils lies beneath a loose 2- or 3-inch surface layer, being practically absent. The loose silty material is practically structureless. The zone of calcium carbonate accumulation is moderately well defined, not in the form of plates, layers, or conspicuous soft or hard nodules, but as uniformly disseminated fine-grained carbonate, giving the layer a grayish-white color on exposure, when not obscured by the ever-present dust. Except when fresh accumulation of material has taken place by settling from the air, effervescence does not occur, in general, above a depth of about 18 inches or 2 feet.

The Wheeler loams occur mainly in 1 large body in the eastern part of the area and in 2 or 3 smaller bodies in the western part. Two areas lie west of Quincy in Grant County, and one is on the eastern end of Frenchman Hills in the southern part of the same county. The main area is bounded on the east by the western boundary of the area of Ritzville loams, and the western boundary extends in an irregular line northward from Eltopia by way of Connell, Othello, Warden, Wheeler, and Marlin. This area has, in general, a rolling surface relief, being a westward continuation of the westwardly sloping plain occupied by the Ritzville soils.

The land is used in the production of dry-farmed grain, all the smoother areas having been used for this purpose for many years. Yields are lower than on the Ritzville soils, ranging from practical failure to more than 20 bushels an acre in unusually wet years. The average yield of wheat is probably about 10 bushels an acre.

Wheeler loams, hardpan phase.—A few very small areas of Wheeler loams are outlined, in which the soil profile contains an indurated calcareous layer. This is designated as Wheeler loams, hardpan phase.

The surface soil is identical with that of the typical Wheeler loams. It is underlain by a layer in which the soil is moderately compact, somewhat lighter in color than the surface soil, and of similar texture. Carbonate is present at an average depth of about 30 inches, and the color of the soil becomes distinctly gray. With increasing depth the lime content becomes greater, and calcareous nodules are present in many places directly overlying the hardpan

zone which occurs at an average depth of about 40 inches. The material in this zone consists of firmly cemented silt and very fine sand and is impervious to water and to root development of plants. In most places it consists of several firmly cemented lenticular plates, from 2 to 4 inches thick, with more friable brownish-gray silt loam or loam intervening and carrying numerous cemented nodules of lime. Underlying the hardpan, the soil is more friable and consists of gray silt loam or very fine sandy loam.

The largest body of the hardpan phase lies about 1 mile west of Hatton. A few other bodies are in various parts of the area. Surface drainage is well developed, considering rainfall conditions, but under irrigation the presence of the underlying hardpan would prevent adequate drainage of the subsoil and give rise to an unfavorably high water table. This land is used in the production of small grains under dry-farming methods, and yields are in general somewhat less than on soils lacking the hardpan.

WINCHESTER SANDS

The surface soils of the soils grouped as Winchester sands consist of dark-gray or black fine sand, sand, and coarse sand to a depth of more than 6 feet. There is no cementation of material in the soil profile, but at a depth of a few inches below the surface the angular grains of sand seem to be somewhat compacted or cemented together, and the sand stands in vertical banks for a short time after being exposed in cuts. The soil material above the gravelly substratum has been accumulated largely by the wind from sand bars exposed along the channel of Columbia River during low-water stages. In restricted localities the sands have a rather loamy texture and the finer material present is probably largely an admixture of wind-borne materials. No noticeable textural differences occur throughout the profile, and in only a few places is there a very slight stratification of the sands by the wind. Lime occurs in but few places within a depth of 6 feet. Very slight amounts are present in a few places at a depth of about 4 feet below the surface. The surface soils are of low organic-matter content, are incoherent, and, where not protected by a cover of natural vegetation, are subject to shifting by the wind. The substrata underlying the Winchester soils commonly consists of stratified beds of sand and gravel, similar to the material forming the subsoils and substrata of soils of the Ephrata series. The material of the Winchester sands is thinnest on exposed ridges and hillocks and in places where it merges into bordering soils of other series. In such localities, the coarser stratified substrata may lie close to the surface.

Black basaltic sand predominates in the Winchester sands, and the amount of that material largely determines the color of the soil. When wet, the sand is coherent, and it is usually only after rains that roads through the sand are passable for motor vehicles.

The sands of the Winchester series are widely distributed throughout the western part of the area. North of Frenchman Hills they make up the greater part of the soils over three townships, and several small areas occur east and south of Saddle Mountains. These soils are widely distributed throughout the western part of Franklin County, but, as they occur in small bodies intimately asso-

ciated with soils of the Ephrata series, they have not been differentiated from such soils but have been included with the group mapped as Winchester and Ephrata sands and sandy loams, undifferentiated.

In most areas of the Winchester sands, the surface relief is hummocky or dunelike. Where these soils occur in large bodies the land consists largely of knolls ranging from a foot to as much as 20 feet in height. Where associated with other soils the relief is commonly somewhat less pronounced, and in many places the areas consist of a series of small knolls and ridges. Drainage courses do not exist in these soils, as the rainfall is absorbed as rapidly as it falls, and a number of former stream channels have been completely buried by the mass of wind-blown sand, such as occurs at the lower end of Esquatzel Coulee, which has been shut off from Columbia River, and a number of smaller stream courses now terminate against banks of these sands.

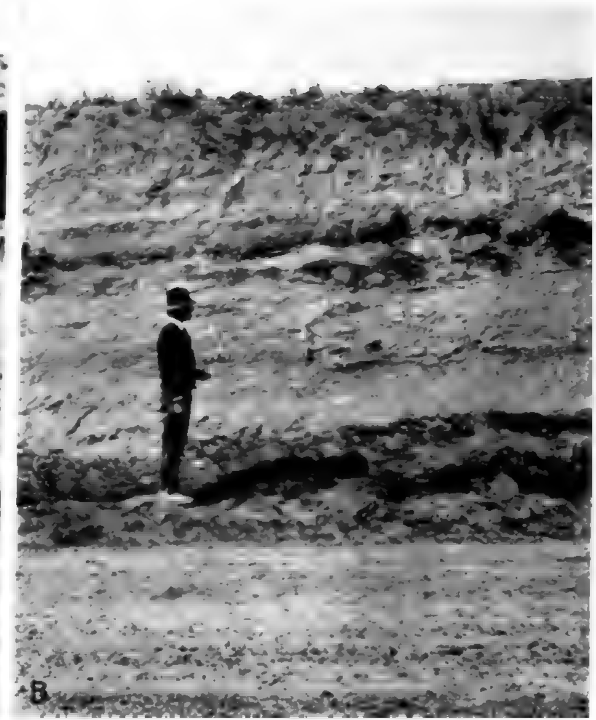
Throughout the greater part of these soils lying west of Moses Lake, the land has been filed on by settlers, and futile attempts have been made at farming without irrigation. Some of the land in Franklin County was also settled. Here the soils are too porous to retain the rainfall, and every attempt to farm without irrigation has been a complete failure. A few small areas of these soils in the vicinity of Pasco are under irrigation and are productive when sufficient water is available. The future development of these soils will depend on obtaining abundant supplies of water at a reasonable cost. The soils are so porous and leachy that very large amounts of water will be required at all times. Under irrigation, alfalfa, berries, grapes, potatoes, and vegetables are grown. Even with an adequate supply of irrigation water, very little of this land would be brought under irrigation, as the surface is so uneven as to make the cost of preparing the land prohibitive. Another feature that renders the land less desirable for irrigation is the tendency of the surface soils to blow when not protected by crops or by natural vegetation. Constant care would be required to preserve the fields in cultivation and to prevent damage to adjacent lands by the drifting sand.

Rabbitbrush, sagebrush, and other desert plants comprise the greater part of the natural vegetation.

WINCHESTER AND EPHRATA SANDS AND SANDY LOAMS, UNDIFFERENTIATED

The substrata of the soils of the Winchester series are, for the most part, composed of the same porous stratified coarse sand and gravel that form the more shallow subsoils and substrata of the soils of the Ephrata series. Throughout the southern part of Franklin County and the western part of Walla Walla County, the wind has removed considerable amounts of the surface soil and subsoil materials of the Winchester sands, forming long parallel ridges and knolls of Winchester materials, between which materials that are typical of the Ephrata soils are exposed. The areas of individual soil types of both of these series are necessarily intimately associated, are small and irregular in extent and occurrence, and therefore have not been differentiated on the soil map.

The surface soils of the included Winchester soils are prevailingly sandy, ranging from rather coarse sand to loamy sand. They



A, Profile of Ritzville very fine sandy loam in T. 18 N., R. 34 E., showing compacted structure of subsoil and substratum and calcareous partings. B, Profile of a Ritzville soil in a road cut

have the characteristic dark color typical of the soils of this series. There is commonly no material change in the color, texture, or structure of these soils to a depth of 6 feet, and below that depth they are underlain by beds of gravel and cobbles.

The surface soils of the Ephrata soils are prevailingly light brown or, where much basaltic material is present over the surface, may be dark grayish brown. The included soils of the Ephrata series are, as a rule, heavier than the Winchester soils, and they consist of loamy sand, fine sandy loam, or sandy loam. In most places the surface soils are underlain, at a depth ranging from about 24 to 36 inches, by dark-gray or nearly black porous coarse sand and gravel, but in some places they directly overlie stratified beds of water-worn basaltic gravel and cobbles. Many of the cobbles have a white calcareous coating which in a few places has cemented a number of the fragments into a firm, hardpanlike material.

This undifferentiated group of soils is extensively distributed throughout the southwestern part of Franklin County, and a number of scattered areas are in Walla Walla County.

The surface relief of these soils as a whole is irregular. The bodies of Winchester soils form a series of irregular knolls and ridges that have a very constant northeast-southwest elongation. The intervening Ephrata soils occupy small irregular areas lying below the Winchester soils, where they form small flats that have a very uniform surface. Drainage of both surface soil and subsoil is excessive.

All attempts at dry farming on these soils have failed and, aside from the slight value the soils may have for grazing purposes, they are of little value without an abundant supply of irrigation water. Even with an adequate supply of water, only a very small part of the area of these soils would be brought under cultivation, as the surface relief is too irregular to make leveling of the land a practical undertaking under present economic conditions. Some of the deeper and heavier-textured areas west of Pasco have been brought under irrigation and are proving to be adapted to a wide range of crops. These soils are also subject to blowing by the wind when not protected by a vegetal cover, and constant care would be necessary to prevent movement of the surface soils.

EPHRATA SANDS

This group includes the sand and gravelly sand members of the Ephrata series.

The surface soils of the Ephrata sands consist of light-brown or dull-brown loose and incoherent sand and gravelly sand to a depth ranging from 15 to 30 inches. Below this the material becomes more compact and is slightly calcareous. In most places the soil material contains more or less gravel and grades into a loose porous mass of sand, gravel, and cobbles, which continues to an undetermined depth, in most places resting on bedrock at a depth ranging from 6 to more than 100 feet. The subsoil of the large area southeast of Quincy consists of coarse basaltic sand of loose incoherent character and low water-holding capacity.

The gravelly areas of this group of soils are confined largely to those bordering Columbia River near Beverly. The gravel ranges from the size of a pea to an inch or two in diameter, and they in-

crease in quantity with depth. The subsoil contains very little of the finer separates, and numerous cobbles and boulders are present.

In the vicinity of areas of the Winchester soils, the color of the surface soil is generally darker than typical, including dark-brown or dull-brown shades.

The largest area of the soils of this group is in Ts. 18 and 19 N., R. 24 E. Here but little gravel is present in the surface soils. A large area is north of Beverly. A large area of very gravelly texture is at Wahluke and southwest of that place, and smaller bodies occur throughout the northwestern part of the area, associated with other old stream-laid materials.

The surface relief is smooth and gently sloping or slightly undulating, especially near the edges of terraces. In the smaller bodies of these soils, where they are intimately associated with areas of wind-blown soils, the relief is hummocky. Some steep-sided coulees traverse the soils of this group, or steep bluff lines separate one terrace from another.

Owing to the gravelly porous character of the soils of this group, drainage is excessive, and the soils are not used in the production of crops without irrigation. Were water available, these soils should be well adapted to the production of fruit and truck crops, though they would require frequent irrigation and large quantities of water.

The natural vegetation consists largely of sagebrush and rabbitbrush. Abandoned fields support a growth of Russian-thistle or tumblemustard and are subject to more or less blowing. None of the land is under cultivation, and it is not adapted to the production of crops without irrigation. It is utilized to some extent as grazing land.

EPHRATA STONY SANDY LOAMS

This group of soils includes the stony sandy loam and stony fine sandy loam of the Ephrata series. Ephrata stony fine sandy loam is more extensive, though large areas of typical stony sandy loam also occur.

The surface soils of these soils consist of light-brown or brown stony sandy loam and stony fine sandy loam to a depth ranging from 10 to 14 inches. The material is loose and incoherent. In most places the subsoils are composed of two layers, the upper one consisting of compact stony fine sandy loam or loam, which in places is mildly calcareous in the upper part and becomes more calcareous with depth. Much of the gravel is slightly coated with lime, especially on the under side. In a few areas the material in this layer may be slightly cemented, but in others no appreciable accumulations of lime are present. The deeper subsoil layer, to a depth of 6 feet or deeper, consists of a mass of gravel and cobbles containing very little interstitial material. Over much of the stone and gravel gray blotches of lime occur.

The soils of this group include variations from the typical soils in which the surface soil may be dark dull brown or dark brown. As such areas are few and of small extent, they are not shown separately on the soil map. Many of these darker variations occur in areas where, owing to favorable moisture conditions, vegetation is more abundant, resulting in the accumulation of a greater amount of organic matter than elsewhere. Areas containing a comparatively high

percentage of basalt gravel are also darker than typical. The grayer variations are in the coulee bottoms, generally bordering soils of the Red Rock and Naylor series.

The quantity of stone over the surface is variable, but in all places it is sufficient to interfere materially with cultivation, and in some places the cost of removing the stone would be prohibitive. The stones range in size from small cobbles to boulders several feet in diameter.

These soils are extensively developed in the vicinity and south of Ephrata, Soap Lake, Adco, and Naylor. Smaller bodies border Crab Creek below Moses Lake to its junction with Columbia River, and some are south of Saddle Mountains and in the vicinity of Othello.

The surface relief is that of a level plain or terrace, with a few gullies or coulees running through it. Drainage ranges from good to excessive, and under irrigation crops would require more frequent irrigation than on soils having better water-holding capacities.

The natural vegetation consists largely of sagebrush, with smaller quantities of rabbitbrush and a few clumps of bunch grass.

In the vicinity of Soap Lake and Adrian, some agricultural development has taken place, and apples, cherries, and some small fruits are produced under irrigation. Practically all the land composed of soils of this group lying between Moses Lake and Soap Lake has been taken up, and considerable areas have been cleared of brush. The cost of removing the large quantities of stones from the surface and of installing and maintaining pumping plants has been prohibitive. Consequently only a few areas are under cultivation.

Illustrative of the cost of development of land of this character is a 30-acre tract 10 miles north of the town of Moses Lake. The land was but partly cleared of stones before being abandoned, and there are now 21 conical piles of stone, the size of the piles averaging 6 feet in height and about 12 feet in diameter. No gravity supply of irrigation water is available for these soils, and water can be obtained only by pumping from deep wells, or by expensive pumping lifts from Columbia River.

EPHRATA SANDY LOAMS

The soils of this group include the very fine sandy loam, fine sandy loam, and sandy loam members of the Ephrata series. All these soils are very similar in color and profile, though under irrigation it would be discovered that they would handle differently and probably require different quantities of water. They occur in irregular scattered bodies and are so similar that they have not been differentiated in this reconnaissance.

The surface soils consist of light-brown or brown sandy loams of varying textures to a depth ranging from 18 to 30 inches, or in places to a depth of 48 inches. The subsoils consist of a porous mass of coarse sand, gravel, cobbles, and boulders extending to a depth of 100 feet or deeper, where basaltic bedrock is reached. Some basaltic sand and gravel are present in many places on the surface, but not in sufficient quantity as materially to affect the physical character of the soil or to interfere with cultivation. The surface soils are non-

calcareous, but a noticeable accumulation of lime occurs in most places directly overlying the coarser subsoil material.

South of Snake River, in Walla Walla County, are five small areas of these soils, in which the surface soil is gravelly sandy loam or gravelly fine sandy loam. These areas are less desirable for cultivation than the typical soils of the group.

A body consisting largely of dull-brown or dark-brown gravelly fine sandy loam occupies the terrace south of Naylor. Areas in Ts. 16 and 17 N., R. 36 E. have subsoils consisting mainly of coarse angular basaltic sand, with very little gravel or finer soil separates. The soils of these areas, in places, very closely approach the soils of the related Warden series, although the water-holding capacity of the subsoil is not much greater than in the typical soils.

In the vicinity of areas of the Winchester soils, the surface soils are darker than typical, owing to the presence of more or less windblown basaltic material. Other bodies of darker-colored soils also occur within areas where moisture conditions have been favorable to vegetal growth. Some areas of these soils, in which the surface soil is light grayish brown, border Wilson Creek and Crab Creek.

A hardpan, consisting of cemented sand and gravel, occurs in these soils in a few places, though in no place is it of more than local occurrence. Several small areas of this character are in the vicinity of Moses Lake, particularly in sec. 21, T. 19 N., R. 27 E., in sec. 22, T. 19 N., R. 28 E., and in sec. 25, T. 17 N, R 29 E.

Several areas of these Ephrata soils mapped in the coulee bottoms are of comparatively recent deposition and in detailed mapping would be differentiated as recent alluvial soils. Bodies of such material occur in the Cow Creek bottoms in the northeastern part of the area, others are at Ralston, Roxboro, and at the head of Hatton Coulee, and smaller areas are associated with other recent alluvial soils.

Several areas of soils of this group mapped within or adjacent to areas of scab land are shallower than typical and in places contain projecting knolls of the underlying basalt. Such areas are of little value under present economic conditions, and under irrigation would prove of restricted value on account of their shallowness and the tendency of seepage water to collect in pockets or basins in the basalt.

The soils of this group are extensively and widely distributed throughout the area. The largest bodies are associated with other soils derived from old stream-laid materials in the western part of the area, extending inland from Columbia River a distance of 40 miles in the northern part but thinning down to narrow areas in the southern part. Areas border Snake River and Washtucna, Esquatzel, and Lind Coulees. Fair-sized bodies are associated with and border scab land adjacent to Cow Creek in the eastern part of the area.

The surface relief of the soils of this group for the most part presents the appearance of a broad, level, terraced plain with steep gravelly slopes separating the different terraces from one another. Old drainage channels or coulees dissect the terraces in places, and in other places the land has an undulating or ridged relief. The surface relief of the fine sandy loam and the very fine sandy loam is less uniform than that of the sandy loam, as the surface soil mate-

rials are subject to greater movement by the wind. In the vicinity of soils of the Winchester series the surface relief is very hummocky.

The gentle slope of areas of these soils promotes good surface drainage, but internal drainage is excessive and the soils have a low water-holding capacity, rendering them less desirable for irrigation than soils with heavier-textured subsoils.

These soils are derived from old stream-laid materials and have their source in a variety of rocks, of which basalt constitutes the greater part. Fragments and boulders of granitic rocks are also present in small quantities.

A small proportion of the land is under cultivation. Virgin areas support a growth of sagebrush, rabbitbrush, and scattered stands of bunch grass. Russian-thistle, tumblemustard, and rabbitbrush now occupy most of the abandoned homestead land. Wheat and rye are grown to a small extent under dry-farming practices. In the vicinity of Moses Lake, Soap Lake, Winchester, Quincy, and Stratford about 7,000 acres of the soils of this group are irrigated by pumping either from deep wells or lakes. The principal crops produced are apples, cherries, pears, alfalfa, watermelons, cantaloups, and some truck crops. When plenty of water is available, alfalfa is allowed to grow in the orchards in order to increase the humus content of the soil, but otherwise clean cultivation is practiced.

Apples yield from 200 to 400 boxes an acre, depending on the number and age of the trees, irrigation practice, and the care given the orchard. Alfalfa yields from 4 to 6 tons an acre from three cuttings.

Table 9 gives the results of mechanical analysis of a sample of the surface soil of Ephrata fine sandy loam.

TABLE 9.—*Mechanical analysis of Ephrata fine sandy loam*

No.	Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
551623	Surface soil, 0 to 14 inches	0.2	1.4	1.7	28.0	19.8	42.2	6.8

QUINCY SANDS

Owing to the small extent of the individual bodies and the indefiniteness with which the soils grade into one another, as well as to the similarity in essential features of color, texture, structure, and possible utilization, the different classes of sands of the Quincy series have not been differentiated in the Columbia Basin area but are grouped as Quincy sands.

The surface soils are brown or light-brown sand, fine sand, or very fine sand of low organic-matter content and incoherent structure, in many places extending to a depth of 6 feet or deeper without distinctive subsoil differences. In many places the surface soil is underlain, at a depth ranging from 12 to 18 inches, by slightly compact very fine sand or sandy loam and in other places by fine-textured stratified compacted water-laid materials. The surface soils are noncalcareous, and the subsoils are calcareous only where made up of stratified sediments.

Normally the surface soils of these sands are light colored and free from conspicuous quantities of finely broken fragments of basaltic material, but, in the vicinity of areas of the Winchester soils, different quantities of dark-colored materials are present, giving rise to darker colors than are characteristic of the Quincy soils. In such locations, the boundaries between the soils of the two series are very poorly defined.

The soils of this group aggregate a large total area, but the greater part of them occurs in bodies too small to be shown on a reconnaissance map and, consequently, have not been differentiated from soils of other series. Several bodies of the Quincy sands occur in southern Franklin County and in the western part of Walla Walla County, and a few small bodies lie in the region around Wahluke and north of Frenchman Hills. The surface relief is, in general, of a hummocky or choppy character, with no orderly arrangement of the knolls and ridges, but in the southern part of the area these soils occur as a series of long low ridges and hummocks with parallel axes that extend in a northeast-southwest direction. Locally the elevation of the hummocks ranges from 2 to as much as 20 feet. The soils are very open and porous, and the rainfall is absorbed so rapidly that surface drainage courses have not developed.

The greater part of this land was filed on by homesteaders during early settlement of the area, but none of it is now under cultivation. All attempts at dry farming have resulted in failure, as the rainfall is low and the soils are not sufficiently retentive of the available moisture. Under irrigation very little of these soils could be profitably brought under cultivation, owing in part to the large volume of water that would be required and to the cost of leveling the ridges and hummocks. The surface soils of these sands are very readily moved by the wind, where not protected by vegetation, even more easily than the surface soils of the Winchester soils, and constant vigilance would be necessary to prevent damage to crops and to adjacent land. Where the water supply is abundant and conditions are favorable to irrigation, these soils would be well adapted to truck crops, alfalfa, and some of the deciduous fruits.

QUINCY AND SAGEMOOR SANDS AND SANDY LOAMS, UNDIFFERENTIATED

As with the Winchester soils, the soils of the Quincy series in many places occur in bodies too small to be differentiated on the map. Under such conditions they are intimately associated with soils of the Sagemoor series, and have been included with a group of undifferentiated Quincy and Sagemoor sands and sandy loams.

The surface soils of the included Quincy soils are predominantly light-brown sands. The subsoils, which in most places occur at an average depth of about 24 inches, consist of stratified and more or less compacted very fine sand and silt that are identical with the material forming the subsoils of the Sagemoor soils. The surface soils are noncalcareous, and the upper limit of the lime zone is identical with the top of the stratified subsoil.

The surface soils of the included Sagemoor soils consist of light-brown or dull grayish-brown sand, loamy sand, fine sand, and light-textured sandy loam. When wet, the surface soils are very dark dull brown, and when dry they may bleach out to very light grayish

brown. The subsoils consist of moderately compact stratified grayish-brown fine sand and silt. At a depth ranging from 4 to 6 feet, the subsoil materials become more firmly compacted and the stratification is more distinct than in the overlying materials. This group of undifferentiated soils occurs entirely in the southern part of the area. Two small bodies are south of Snake River, in Walla Walla County, but the greater development is north of Pasco, in Franklin County. The surface relief is very irregular, the soils consisting largely of narrow elongated knolls and ridges with small intervening flats. The ridges range from a foot to as much as 20 feet in height. All bodies of like elevation are approximately parallel and lie in the direction of the prevailing winds. The ridges are composed of soils of the Quincy series and the lower intervening flats of Sagemoor soils. Rainfall is rapidly absorbed, and surface drainage ways have not been developed.

Practically all this land has passed into private holdings. None of it, however, is utilized for crop production, as it is not adapted to dry-farming methods of grain production under the existing rainfall conditions, and a supply of water for irrigation has not yet been developed. The value of the land is governed almost solely by the use that can be made of it for grazing.

Without a supply of irrigation water, the soils of this group are valueless for cultivation. With a supply of irrigation water only a very small part could be economically utilized for crop production, owing to the cost of preparing the land for irrigation. Under irrigation there is some doubt as to the long-continued value of the land, as the soils of the Sagemoor series are underlain by comparatively impervious subsoils, and unfavorable conditions of subdrainage, that could not be corrected by drainage at a reasonable cost, would probably develop.

SAGEMOOR SANDY LOAMS

This group of soils includes the fine sandy loam and very fine sandy loam members of the Sagemoor series. Small areas of typical Sagemoor silt loam, which, on account of their intimate association with the sandier soils of the Quincy series, are very irregular in outline, are also included.

The surface soils of these soils consist of light-brown or light grayish-brown fine sandy loam or very fine sandy loam, extending to a depth of about 12 inches. The subsoils are light-gray or light grayish-brown fine sandy loam or very fine sandy loam to an average depth of about 40 inches. The substratum is gray or grayish-brown extremely compact and stratified silt and clay, which generally contain light-yellow, dull-brown, or rust-brown iron stains. The surface soils are in places calcareous, and the subsoils are everywhere slightly calcareous. The substratum is intermittently calcareous, and it is believed that much of this material is of siliceous origin. The material composing the substratum is exposed in places to a depth of more than 300 feet and is characterized by transverse fissures or cracks, in which weathered material from the surface soil has accumulated. In places stones and boulders occur over the surface or in the soil. Many of the boulders are massive and in general of granitic origin, probably having been carried by blocks of ice into the lake that at one time covered this region.

The Sagemoor sandy loams are extensively developed in the southern and western parts of the area. Two of the largest bodies are south of Saddle Mountains and at the junction of Weber and Lind Coulees. Smaller areas occur throughout the same general section and in the area of old valley-filling soils bordering Snake River. In general, the Sagemoor sandy loams occupy intermediate positions between soils of the Burke series and those of the lower stream-laid terraces.

The surface relief is gently undulating or moderately rolling. Areas bordering the Burke soils are in general steeper than others, and here slight erosion occurs following unusually heavy rainfall. Run-off, however, is of very infrequent occurrence, except over very small areas.

All drainage channels and valleys through the soils of this group are the result of former climatic conditions. In some areas, stream courses have not developed, and the moisture is absorbed as fast as it is received. Under natural moisture conditions, drainage is adequate, but under irrigation, in some areas the more compact subsoils would retard the escape of waste irrigation water and unfavorable moisture conditions would soon develop. Surface drainage is well developed. The larger part of the soils of this group were cleared of their natural vegetation at the time of first settlement of the area, but much of the land has since been abandoned, as a large part of it lies in the area of low rainfall, and the production of small grains by dry-farming methods did not prove practical. The larger body of these soils north of Snake River is still under cultivation, and fair yields of wheat and rye are obtained. In the large area on the southern slope of Saddle Mountains no attempts are now being made at farming. Here, the soil is light textured and the surface soil is readily transported by the wind when the cover of natural vegetation is removed.

Irrigation is essential to the full development of the soils of this group and, aside from the cost of obtaining a supply of water, the value of the several bodies would depend on the cost of preparing the land for irrigation and the maintenance of thorough drainage. In the area north of Snake River irrigation costs would not be excessive, and drainage would probably be satisfactory. In the other bodies, the surface relief is less favorable for the distribution of irrigation water, resulting in higher cost of preparing and handling the land, and the character of the subsoil indicates that considerable trouble would be had in maintaining satisfactory drainage.

KOEHLER SANDS

This group consists of undifferentiated bodies of the sand, fine sand, and very fine sand of the Koehler series. The surface soils are grayish-brown or light-brown sands to a depth ranging from 12 to 20 inches. Small quantities of fine water-worn gravel of mixed origin are present in most places. The subsoils consist of sand or loamy sand to a depth ranging from 2 to 3 feet. They are underlain by a substratum of dense hard white limestone resting on compacted and stratified fine sand and silt, which very commonly carry small fragments of the underlying limestone, although in less amounts than is usual in the subsoils of the related Burke soils.

The Koehler sands are similar to the Burke sands in all essential respects, except that the surface materials have been subjected to considerable shifting and sorting by the wind. The subsoils of the soils of the two series are similar in almost every respect.

An area of several square miles of the soils of this group lies at the eastern end of Frenchman Hills, but the most extensive bodies are on the high undulating tableland west and southwest of Scooteney Lake, where 50 or 60 square miles of these sands occur. A few small areas are west of Eltopia.

The surface relief of these soils is very hummocky, although the general elevation of the tops of the hummocks is in few places more than 3 feet above the intervening areas. All the surface soils are readily moved by the wind, but at present the material is comparatively stable, owing to the cover of natural vegetation, which consists mainly of sagebrush, rabbitbrush, and grasses. Surface drainage is well developed, but the movement of moisture through the subsoil is prevented by the impervious limestone and underlying strata.

Practically all this land is in private holdings. Much of it was at one time cleared of brush and largely sown to small grains, but such attempts almost invariably resulted in failure and led to abandonment of the land. In a few places in the section west of Scooteney Lake the land is still being sown to rye, and the farm income is supplemented by grazing cattle on the adjacent vacant land. Soils of this group have practically no value for dry-farmed crops, and the yields are small, even in years of favorable rainfall. Under irrigation considerable areas of the land could be brought under cultivation, although the cost of leveling would be high. Large areas of these sands would have permanently good drainage conditions, as they occur in the immediate vicinity of deeply cut drainage courses or near high terrace slopes that would afford means of escape for the excess water from the subsoils. Areas farther removed from such natural drainage outlets would very soon develop unfavorably high underground waters that would impair the value of the land or render it worthless for crop production. Drainage would then be necessary if farming operations were to be continued, and the cost of draining the land would be added to the other costs connected with irrigation. Where conditions are favorable to irrigation, these soils would have a very general crop adaptation, but, owing to the ease with which unprotected surface soils would be disturbed by the wind, a permanent cover of vegetation would be an important factor.

BURKE SANDS

The soils of this group consist of undifferentiated bodies of very fine sand and fine sand.

The surface soils are composed of light grayish-brown or light-brown sand to a depth ranging from 10 to 15 inches. They may be underlain by materials of similar texture and usually of somewhat lighter color, but the subsoils are more commonly very light-textured moderately compact fine sandy loam. The subsoils, in turn, rest directly on a limestone substratum. The surface soils are noncalcareous, and the upper part of the subsoil is very slightly calcareous, the amount of lime increasing with depth. The surface soils contain small quantities of fine water-worn gravel of mixed origin, and the

subsoil almost everywhere carries more or less angular and water-worn fragments of the underlying limestone formation.

The soils of this group are extensively developed in the western part of Grant County, where they form an almost unbroken body, extending along nearly the entire length of the tops of Frenchman Hills. A very extensive area lies northeast of Beverly on the southern slope of the same hills. Small isolated bodies of the sands occur throughout the section between Beverly and Othello.

The surface relief of these soils is undulating or rolling. Numerous shallow drainage channels traverse a rather large part of the land and serve to remove the run-off from heavy storms. Surface drainage is somewhat excessive, and any moisture passing into the subsoil moves along the upper surface of the limestone substratum and finds its way into nearby stream channels.

A few small bodies along the crest of Frenchman Hills are under cultivation, but the greater part of the land has been abandoned. The soils are too porous to retain moisture well, and the production of crops by dry-farming methods is exceedingly uncertain.

Under irrigation, the cost of leveling the land and of preventing the movement of the surface soils by the wind would be the principal problems to be met. Most of the areas occupied by these soils are well supplied with surface drainage channels, and it is not probable that, under irrigation, any difficulty would result from unfavorable subsoil moisture conditions. The surface relief is too uneven for extensive irrigation development by flooding or check methods, and if water were available the greater acreage would need to be used for crops that could be grown under irrigation by using the furrow method.

BURKE SANDY LOAMS

This group consists of the fine sandy loam and very fine sandy loam of the Burke series.

The surface soils of the Burke sandy loams, to a depth ranging from 10 to 14 inches, are light grayish-brown fine sandy loam or very fine sandy loam. The subsoils consist of light grayish-brown fine sandy loam or very fine sandy loam, that extends to an average depth of about 3½ feet below the surface. The subsoils rest directly on the substratum of hard limestone, characteristic of the Burke soils. The surface soils are friable, the subsoils are but slightly compacted, and the substratum is impervious. The surface soils are noncalcareous, the subsoils are slightly calcareous, and the substratum is a formation of lime carbonate. The surface soils carry small quantities of fine water-worn gravel. Fragments of the underlying limestone occur in various quantities throughout the subsoil and are occasionally brought to the surface by burrowing animals. Just west of Shano and Frischnecht an area of several square miles of the Burke sandy loams merges into adjacent bodies of soils of the Ritzville series. Distinctions between soils of the two classifications are very poorly developed in this locality. The color, texture, and surface relief of the surface soils are very similar or identical, and the substratum of limestone is commonly more than 6 feet below the surface. A detailed survey of this part of the area might result in several changes in the relative extent of the several soil types.

The most extensive development of these soils is in the western parts of Franklin and Adams Counties, and in Grant County. Rather large areas associated with extensive areas of soils of the Koehler series, are west and south of Scooteney Lake. A fair-sized body is in the vicinity of the village of Burke, and an almost unbroken area occurs on the southern slopes of Frenchman Hills throughout nearly their entire length. A large area of these soils is just east of Othello, and a number of different-sized bodies occur between a point a short distance south of Sieler northward nearly to Stratford and Wilsoncreek.

The surface relief of these soils differs widely in different areas. In the most southerly bodies, the soils occur on the nearly level tops of extensive mesas, or tablelands, and the smooth surface relief is somewhat broken only where the soils merge into adjacent soils of the Koehler series or where they occupy positions along the upper edges of eroded terrace slopes. On the southerly slopes of Frenchman Hills, the surface relief ranges from moderately to very steeply sloping and rolling, and in many places the areas are deeply cut by local drainage ways. In the bodies extending from Sieler northward, the variation in surface relief is slight, many areas being exceedingly uniform, although small bodies occupy narrow steeply eroded slopes adjacent to some of the larger coulees. Similar surface relief occurs in the large area near Othello. Drainage conditions are good, so far as rainfall is concerned, but under irrigation many areas would be very poorly drained because of obstructed subsoil movement of waste waters and the absence of natural drainage channels.

The greater part of the soils of this group has been abandoned owing both to the tendency of the surface soils to drift when vegetation has been removed and because the soil does not retain the rainfall long enough to mature crops. This latter condition varies considerably owing to the different textures of the surface soils. Where the soils approach the lighter-textured materials of the Burke sands, wheat cannot be profitably grown year after year, and the yields of rye are small and not very satisfactory. In the areas of heavier-textured soils, as well as in the deeper areas, much of the land is dry farmed to both wheat and rye, the latter usually giving the more satisfactory returns. The tendency of the surface soils to be affected by the wind will require great care in their cultivation.

BURKE AND EPHRATA FINE SANDY LOAMS, UNDIFFERENTIATED

This group consists of the fine sandy loams of the Burke and Ephrata series, which occur in such small intimately associated bodies and so irregularly as to preclude the possibility of separation of the two soils in a reconnaissance survey.

The surface soils consist of light grayish-brown or light-brown fine sandy loam, in which numerous rounded or subangular fragments of limestone, and to less extent basaltic gravel, occur. At a depth ranging from 18 to 48 inches is either a limestone hardpan or a mass of loose porous gravel of basalt and limestone, which extends to a depth exceeding 6 feet and in most places overlies either limestone hardpan or old stratified lake-laid sediments. Cuts and pits

expose the underlying gravel or hardpan and show that it conforms more or less in general outline to the surface relief of the area occupied by these soils.

Only one body of the Burke and Ephrata fine sandy loams, undifferentiated, occurs in the area surveyed. It occupies about 25 square miles west of Burke in Grant County. The surface relief is characterized by gently undulating swells and depressions more or less parallel to each other and with a general north and south trend.

The soils of this group are of mixed mineralogical origin. The surface soils and upper subsoil layers are derived from water-laid sediments that were deposited during the period when the waters of former channels of Columbia River traversed this part of the area. The lower subsoil layers are also composed of materials laid down by water, but at a much earlier period, and they consist of stratified siliceous and calcareous fine sand and silt, with a capping of resistant limestone.

The land has been largely cleared of its natural growth of brush, but rather large areas have been abandoned and are now occupied by Russian-thistle and tumblemustard. Where cultivated, fair yields of wheat and rye are obtained in favorable seasons.

The greater part of the soils of this group could be placed under irrigation without incurring heavy expense for leveling. The soils are, however, not very desirable for irrigation, owing to the presence of the underyling substrata of limestone and other stratified sediments. These materials would effectually prevent the normal internal drainage of the subsoil, and it would probably be difficult to prevent water-logging of the land. The construction of drains would be difficult, and a close investigation of conditions might develop the fact that such operations would not be practical.

WARDEN SANDY LOAMS

This group of soils includes the very fine sandy loam and the fine sandy loam of the Warden series. In a detailed survey, the occurrence of small included areas of Warden sandy loam also might be recognized.

The surface soils are light brown or dull brown to a depth ranging from 18 to 24 inches, where there is a more compact zone, usually of slightly heavier texture. A slight lime accumulation occurs in most areas at the point of change from surface soil to subsoil and increases with depth, to a depth ranging from about 40 to 48 inches. As the lime content becomes greater, the color becomes more gray. The subsoils, to a depth of 6 feet, consist of stream-laid sediments, generally showing some stratification, but of sandy loam, loam, or in places silt loam texture. The deeper subsoil layers are in most places very friable and are grayish brown or light brown. In places the subsoil is gray and compact and closely resembles the material underlying the Sagemoor soils. This condition is more or less typical of the areas mapped between Wheeler and the junction of Lind and Weber Coulees. Small gravel occur over the surface in many places but are less plentiful in the surface soils and subsoils. However, they are nowhere present in sufficient quantity to interfere with cultivation. The soils of this group occurring northeast of Soap Lake are grayer than typical, consisting of light grayish-brown sandy loam or very fine sandy loam.

These soils are extensively developed and widely distributed throughout the area. In general, they occupy positions intermediate between the loessial soils of the Ritzville series and soils of the Ephrata series. This condition is well developed on the terrace about 2 miles south of Connell. They also occur as outwash terraces bordering some of the larger coulees. Some of the largest areas are at Bassett Junction, Warden, and northwest of Stratford. In Franklin County, several large areas are between Pasco and Scooteney Lake and in the vicinity of Connell. Smaller areas border Frenchman Hills, and others are marginal to bodies of scab land and to the larger coulees.

The areas of these soils north of Stratford, Adco, and Soap Lake are hilly or rolling, but, in general, the soils of this group occupy moderately sloping or almost flat benches which have been eroded to slight depths by drainage ways, producing a gently undulating or rolling surface relief. Drainage is well developed, and the soils should prove well adapted to irrigation.

The soils of the Warden series are derived from stream-laid materials, largely of basaltic origin, though they are recognized as containing some granitic material. Under irrigation these soils should prove to have a much higher water-holding capacity than the soils of the Ephrata series, but owing to their position, where subject to drainage and seepage from the loessial Ritzville soils of greater elevation, areas of impaired drainage might be developed under extensive and long-continued irrigation of the more elevated land.

The natural vegetation, consisting largely of sagebrush, has been cleared from about 2 percent of the land, and average yields of wheat and rye are obtained in favorable years. In order to prevent drifting, care must be exercised in preparing the soil for crops.

Table 10 gives the results of mechanical analyses of samples of the surface soil and subsoil of Warden fine sandy loam.

TABLE 10.—*Mechanical analyses of Warden fine sandy loam*

No.	Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
551517	Surface soil, 0 to 12 inches	0.8	3.4	5.3	55.9	10.0	19.8	4.1
551518	Subsoil, 12 to 38 inches	.4	4.0	5.6	25.4	6.2	42.3	15.4
551519	Subsoil, 38 to 72 inches	1.2	3.8	2.7	31.4	11.2	43.2	5.8

WARDEN SILT LOAM

Warden silt loam, to a depth ranging from 10 to 14 inches, consists of brown or light reddish-brown smooth-textured silt loam overlying a brown or rich-brown subsoil which is somewhat stratified but in general is of about the same texture as the surface soil. Lime accumulations are of irregular occurrence, in many places being absent to a depth of 6 feet. Where present, lime generally occurs at a depth of 48 or more inches, and it gives the subsoil at this point a lighter-brown color.

This soil has a richer-brown color than other soils of the area. It has been correlated as a soil of the Warden series because of the similarity of profile. In detailed mapping it might be differentiated

as a soil of a distinct series, owing to color differences which are probably associated with more advanced oxidation and weathering.

Only one body of this soil, embracing about 18 square miles, occurs in the area. It is an elongated body extending from a point about 3 miles west of Quincy eastward to Winchester. The surface relief is smooth and gently sloping, affording good surface drainage, though subdrainage is slightly restricted in local areas. The land should prove well adapted to irrigation.

This soil is stream laid and of mixed origin, basaltic material predominating, with smaller quantities of granitic and other acid igneous rock.

The natural vegetation, which consisted largely of sagebrush, has been cleared from most of the land, and the fields which have not been abandoned are utilized in the production of dry-farmed grain or in fruit production with irrigation. Water is obtained for orchards by pumping, but, owing to a rather high lift and the inexperience of the operators, several orchards on this soil have been abandoned.

Wheat produces from 10 to 30 bushels an acre and rye slightly less, depending on the amount of moisture available and weather conditions during the period in which the grain is filling and ripening. Bearing orchards yield well when sufficient water is available. The incorporation of organic matter should not be neglected on this soil or on other soils in the area.

RINGOLD CLAY LOAM

The 10- to 14-inch surface soil of Ringold clay loam consists of yellowish-gray or light-gray clay loam which is low in organic matter and has a tendency to bake after wetting. The subsoil is compact yellowish-gray or light-gray silty clay loam, in places mottled with yellow. In general the subsoil becomes slightly heavier with depth and in most places rests on stratified sedimentary deposits at a depth below 5 feet. Both surface soil and subsoil are highly calcareous.

Several small areas of this soil lie adjacent to Columbia River where the soil occupies an intermediate position between the recent alluvial river-bottom soils and the steep bluffs of the White Bluffs formation. Aside from the areas bordering the river, two bodies are east of Corfu, where they occur as outwash from the slopes of Saddle Mountains. Two very small bodies are in T. 13 N., R. 29 E.

The surface relief ranges from gently to steeply sloping, the steeper slopes adjoining the elevated areas from which the soils are derived. Many drainage ways dissect the upper parts of the slopes. The soils are still in the process of accumulation and are overflowed for short periods following storms, especially on the lower margins of the fans. Alkali is not present in injurious quantities. The soils are well adapted to irrigation.

Fruits and alfalfa are produced under irrigation, and good yields, particularly of alfalfa, are obtained. This land is comparatively free from frost and could be utilized to a greater extent for fruit and berry production were irrigation water and transportation facilities available. No dry farming is practiced, and such areas as are not

irrigated support a natural growth of sagebrush and grasses and are utilized as pasture land.

ESQUATZEL VERY FINE SANDY LOAM

The surface soil of Esquatzel very fine sandy loam consists of a 12- to 15-inch layer of light-brown or brown friable smooth-textured very fine sandy loam. The upper subsoil layer is light yellowish-brown or light-brown slightly compact very fine sandy loam, or in places loam, and it is underlain by stratified materials which are usually of somewhat lighter texture. In places, gravel is present below a depth of 3 feet, and it extends to the underlying bedrock. This soil includes a few small shallow areas in which bedrock approaches within a few feet of the surface. The subsoil in most places is calcareous, but in a few places only parts of it effervesce with dilute hydrochloric acid.

This soil occupies the coulee bottoms, where it has been deposited largely by running water, though it is seldom overflowed, except by run-off from the higher land, at which time a slight deposition of material is made. The surface soil is mixed more or less with wind-laid material derived from adjacent fine-textured soils of the Ritzville series and deposited during dust storms.

Several long narrow bodies occupy the bottoms of Weber, Rocky, Bowers, Lind, and Rye Grass Coulees, and Smith Canyon. Numerous small areas are associated with the Ritzville soils throughout the northeastern part of the area. Most of the bodies associated with scab land are shallow and in many places have a grayer subsoil than typical.

The surface relief is flat, with a gentle slope in the direction of stream flow. Drainage is adequate under existing conditions, though with extensive irrigation of the uplands unfavorable seepage and drainage conditions would probably result unless prevented by costly drainage works.

All the areas of this soil occupy positions close to the lines of stream drainage and under irrigation would receive waste surface and seepage water originating from adjacent higher lands. When the land is once water-logged such conditions, together with the small extent of the individual bodies, would render the reclamation of most of the land by drainage impractical, and, aside from the fact that such land might furnish some grazing, it would have little if any value under irrigation.

Water for the irrigation of this soil is now available only by pumping from deep wells, and such operations have not proved successful. The land is used largely for the production of grain by dry-farming methods.

Esquatzel very fine sandy loam, dark-colored phase.—The surface soil of Esquatzel very fine sandy loam, dark-colored phase, consists of a 10- to 14-inch layer of friable brown or dark-brown fine sandy loam containing a large proportion of silt and fine sand. The subsoil is composed of light- or dark-brown stratified sediments of sandy loam, loam, or silt loam texture. Some gravel and cobbles are present throughout the soil profile, and in many places, at a depth of 6 feet or deeper, a gravelly substratum that extends to bedrock is reached. A few areas occur which are shallower than typical and in which bedrock approaches within 6 feet of the surface.

This soil occurs only in the southern part of the area, occupying the bottom land adjacent to Touchet and Walla Walla Rivers. The surface relief is smooth and gently sloping. Drainage is good, except during periods of high water in the river when the land is overflowed for short periods. With a judicious use of water the soil could be irrigated successfully and should prove well adapted to all crops common to the area.

It is not considered probable that irrigation would result in a noticeable development of water-logged areas. The channels of the streams lie at a fair depth below the land surface, and, as the areas of this soil are not extensive, the waste underground waters could easily escape. No large areas of irrigable land lie adjacent to the bodies of this soil, and any waste water from the higher-lying irrigable land would reach Touchet and Walla Walla Rivers through tributary drainage channels and not by passing over this soil.

In the bodies along Touchet River a rather large proportion of the land is under cultivation, and only small bodies retain their growth of natural vegetation. Along Walla Walla River the greater part of the land is under irrigation by diversion of water from that stream and is utilized for growing alfalfa, grain, and fruits.

WASHTUCNA VERY FINE SANDY LOAM

The surface soil of Washtucna very fine sandy loam consists of a 12- to 18-inch layer of light grayish-brown smooth-textured friable very fine sandy loam. The upper subsoil layer, to a depth ranging from 30 to 40 inches, is slightly compact light-gray or light grayish-brown fine sandy loam, loam, or light-textured silt loam. The underlying material is light grayish-brown or light-gray loamy fine sand, loam, or silt loam, which shows some stratification in most places. Bedrock lies at a depth ranging from 4 to 8 feet.

Typical areas of Washtucna very fine sandy loam are at Washtucna, and bordering on, and associated with, areas of scab land north of this place. Large areas are near the mouths of Lind and Weber Coulees, and small areas are associated with soils of the Ritzville and Ephrata series. Several small areas in T. 11 N., Rs. 30 and 31 E., and in T. 9 N., R. 29 E. have surface soils somewhat heavier than typical. Such areas are typically silt loam and in detailed mapping would be separated as another soil type.

The surface relief is flat or gently sloping, and underdrainage is poorly developed.

This soil is of recent accumulation but is seldom overflowed except by local lateral wash during periods of unusually heavy precipitation. Accessions of wind-borne material are made from time to time with each succeeding dust storm. Run-off from higher lands frequently collects over the surface and remains until evaporation or percolation removes it. Small alkali-affected areas occur in this soil, particularly in one area 2 miles northeast of Ruff.

The natural vegetation consists of sagebrush, rabbitbrush, giant ryegrass, and other bunch grasses. When cleared Washtucna very fine sandy loam is productive of wheat and rye, also of alfalfa, where water is available. With extensive irrigation development in this area, the soil would be in need of artificial drainage. Alkali

salts would be of universal occurrence until the salts were leached out and the land drained.

WASHTUCNA AND ESQUATZEL LOAMS, UNDIFFERENTIATED

The soils of this group consist of the sandy loams, fine sandy loams, and silt loams of the Washtucna and Esquatzel series, in which the soils of the two series are so intimately associated as to preclude the practicability of separation in the present survey. Although they have been differentiated in previous surveys, they have been combined in this area to facilitate the publication of the map on the scale adopted.

The surface soils range in texture from sandy loam to silt loam and in color from light grayish brown to brown. Little indication in the surface soils, such as color, exists as a guide in separating the soils of the two series, but the subsoils are dissimilar, in that those underlying the Esquatzel soils are light brown or light grayish brown to a depth of more than 6 feet, and the subsoils of the Washtucna soils are light grayish brown or light gray. The materials composing the soils of both series are stratified in places, and they are underlain at a depth exceeding 4 feet by gravelly substrata resting on basaltic bedrock. Slight accumulations of lime occur in places in the surface soils and subsoils of the soils of both series.

Several areas of this group of soils are in Washtucna Coulee, at the head of Esquatzel Coulee, and a large area occurs in T. 14 N., R. 30 E.

Throughout a number of the bodies of the soils of this group thin irregular strata and lenses of white flourlike very fine sand occur at different depths below the surface, and in many places it is exposed in the banks of the shallow stream ways. There is no regularity whatever in the depth, thickness, or extent of this material, and its origin is unknown. The most prominent areas are in the bottom of Washtucna Coulee between Kahlotus and Connell. The soils of these two series are closely associated, both in surface relief and in the color and texture of the surface soils. In many places there is no marked line of separation between the different soil types, and in many places the distinctions were so vague that no attempt was made at a separation in the course of the field work.

In general, the surface relief of the soils of this group is very uniform, being broken only by the meanders of a few shallow stream ways. The larger number of the bodies slope gently in the direction of the stream drainage, but in the extensive body along Washtucna Coulee, the surface relief is largely a series of low spreading alluvial fans below the mouths of the smaller tributary coulees. The discharge from such channels has not been of sufficient volume to maintain a continuous channel along the axis of Washtucna Coulee, and a series of shallow basins has been developed by the merging of opposite fans. Between Kahlotus and Connell, the structure of the basalt has resulted in the formation of a number of enclosed basins, in which the surface waters are impounded until removed by percolation and evaporation. The most prominent of these is the one now occupied by Sulphur Lake. This depression is almost 100 feet lower than Connell and about 50 feet lower than Washtucna Lake.

With extensive irrigation of adjacent lands, the moisture conditions of the soils of this group would be unsatisfactory, owing to the inflow of seepage and waste surface waters from the higher lands. Such excessive moisture conditions would be difficult, if not impossible, to correct.

Small areas of these soils are utilized in the production of dry-farmed wheat and rye. Where not cultivated they are used as grazing land.

BEVERLY AND PASCO SANDS AND SANDY LOAMS, UNDIFFERENTIATED

The soils of this group of undifferentiated soils consist of the sands, fine sands, fine sandy loams, and very fine sandy loams of the Beverly and Pasco series.

The Beverly soils are brown or light-brown recent alluvial soils underlain by deposits of coarse gravel and cobbles. The gravel is largely of basaltic origin, though a considerable amount of granitic material and some boulders are present. Mica is very noticeable throughout the soil profile. The surface soils in places contain much gravel and cobbles, and stony and gravelly bars and low-lying areas, which are inundated during periods of high water, have been included.

The Beverly and Pasco soils are differentiated on the darker color and finer texture of the subsoils of the Pasco series, though the soils of the two series intergrade without distinctive lines of demarcation. Many variations in the color, texture, and character of the subsoils occur within short distances. Areas of river wash have been included in this group on account of their small extent. Such areas are entirely nonagricultural, owing to the porous gravelly character of the surface soil and subsoil and to the fact that they are overflowed for months at a time during high-water stages of the river.

The soils of this group in general occupy gently sloping benches intermediate between the gravel bordering the river channel and the higher distant terraces. Several small areas are in the vicinity of Pasco, and others are along Columbia and Snake Rivers northwest and east of that place. Areas of these soils occur only on the lower river terraces and river flood plains. The lower-lying terraces are overflowed for short periods. Drainage is excessive, except during floods.

Sagebrush and bunch grass occupy these soils, except where the land is cleared and placed under irrigation. Moisture conditions are very deficient throughout all bodies of these soils, both because they are situated in the part of the area having the lowest precipitation and also because they are very porous and leachy. Without irrigation the soils are valueless for growing cultivated crops and have only slight value for grazing purposes. The development of soils of this group lies wholly within districts where irrigation works have been completed. The largest developed area is in the vicinity of Pasco, where water is pumped both from wells and from Columbia River, and the area south of Trinidad is also irrigated by pumping from the river. Irrigation has been attempted on a number of other areas of these soils, either by pumping from the river or by gravity diversion, but the cost of operation of the pumping plants, the difficulty of maintaining diversion works, and the dis-

tance of many of the tracts from markets have proved insurmountable obstacles. With an adequate supply of irrigation water at a reasonable cost, irrigation of these soils should prove feasible for the production of any crop suited to the area. The soils have been proved to be productive and have the further advantage that they are largely situated in a section where climatic conditions favor the early maturity of fruits and vegetables. Orchard crops, berries, grapes, truck crops, alfalfa, and potatoes are produced on the irrigated areas.

Table 11 gives the results of mechanical analysis of a sample of the surface soil of Beverly fine sandy loam.

TABLE 11.—*Mechanical analysis of Beverly fine sandy loam*

No.	Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
551516	Surface soil, 0 to 26 inches	3.8	13.5	8.0	36.4	30.6	3.8	4.2

NAYLOR AND RED ROCK SOILS, UNDIFFERENTIATED

The surface soils of the undifferentiated Naylor and Red Rock soils and prevailingly light grayish brown, light gray, or drab, with included local variations in color ranging to dark-brown tints. The texture of the surface soils ranges from fine sandy loam to clay, most of the soils being of the lighter textures. The lighter-textured materials usually occur on slightly elevated benches or terraces and include much brown material which is more closely related to the Esquatzel or Washtucna soils, and the heavier-textured soils are usually confined to lower-lying areas where the finer sediments accumulate during periods of overflow from the local stream channels. They are more representative of the Naylor and the Red Rock series. The subsoils are in general somewhat lighter colored than the surface soils and in places are streaked or mottled with either lighter or darker tints. The subsoils are normally fairly compact, and rather firmly cemented strata have been observed within local areas. The substratum consists either of the basalt bedrock or of thin beds of water-worn gravel overlying the basalt. The gravelly substratum is of more limited occurrence than the bedrock and is largely confined to the deeper areas of soil along Crab Creek near the junction of Lind Coulee. In many places the surface soils and subsoils are plainly stratified, but the thickness and extent of the individual strata are subject to wide variations. Both surface soils and subsoils are commonly calcareous.

The material from which the soils of this group has been derived has been largely laid down by recent overflows of the streams and is being further accumulated with every overflow. Some wind-blown materials derived from the fine-textured loessial soils of the adjacent uplands are also included. The material has been largely derived by erosion of the finer materials on the adjacent plains, but along the lower part of Crab Creek, sand derived from bars along Columbia River and from adjacent deposits of wind-blown sand is drifting over the surface of these soils, and in some places the soils are being buried under the fronts of small dunes. Drainage is poorly developed, as

the land surface in most places is but little above the normal level of the water in Crab Creek.

The largest areas of these soils occur along Crab Creek between Moses Lake and Columbia River, and a number of bodies are south of Naylor and along Wallace Creek.

The surface relief of the soils of this group is flat and cut by the meanders of local stream channels. Alkali salts are present throughout much of the area occupied by these soils, especially in the section between Othello and Columbia River.

Saltgrass and greasewood occupy the more strongly alkali affected areas, and sagebrush, rabbitbrush, giant ryegrass, and bunch grasses maintain a vigorous growth in the better-drained areas. The soils of this group are utilized very largely for grazing. Cultivation has been attempted in a number of places, but is being continued only in a small area near Taunton, where a few small apple orchards are being irrigated by diversion of water from Crab Creek. Drainage is poorly developed in this district, and the trees are becoming seriously affected by the development of alkali salts. On the whole, this group of soils has no value for cultivated crops, as it would be practically impossible to maintain adequate drainage either for the removal of the alkali now present or to prevent further accumulations.

MUCK AND PEAT

The classification muck and peat embraces areas of soil materials which are derived largely from the decomposition of organic matter. In their typical development the two types of material are dissimilar in physical and chemical properties, but in the Columbia Basin area they intergrade and are so intimately associated as to render differentiation impractical.

Muck is dark-brown or black material composed largely of thoroughly decomposed organic matter mixed with a fair quantity of mineral matter. Muck areas are more extensively developed than are those of peat. Peat soils are brown or dark brown and are composed of a fibrous mass of partly decomposed organic matter in which very little mineral matter is present.

The depth of the deposit of organic matter is variable. The deposit is generally deepest in the center of the marshy areas in which the materials occur, with a gradual thinning out of the organic material and increase in the content of mineral matter with approach to the margin.

In the center of the former Crab Lake, near Marlin, a deposit 6 or more feet thick, of muck and peat, occurs, and this thickness is more or less constant over the lake area. Along the channel of Rocky Ford Creek, in the next largest body in the area, the thickness of the organic or cumulose deposit ranges from 2 to 4 feet, and other bodies are of about the same thickness.

Under natural conditions drainage is poorly developed. No noticeable quantities of alkali are present in these materials.

Muck is very productive when drained and placed under cultivation, but peat generally requires the addition of mineral fertilizer for successful crop production. The largest area of muck and peat occurs at Wilsoncreek and west of Marlin and is entirely under cultivation. Wheat and oats yield exceptionally well, wheat averaging about 50 bushels an acre and oats about 75 bushels, but yields

of as much as 120 bushels of oats have been reported. Timothy and alsike clover produce from 2½ to 5 tons an acre. Where not cultivated, the land affords excellent pasture.

DUNE SAND

Dune sand consists of light or dark grayish-brown fine sand and medium sand. The material occurs in mounds or dunes and is shifted with each successive windstorm. The lighter or darker color of the sand is caused by the relative proportions of light-colored quartz sand and of dark-colored basalt sand. Some areas are decidedly dark, especially when wet.

The dunes are of irregular distribution, with small wind-swept sandy areas intervening, which, even were they large enough to be important, could not be put under cultivation, owing to the shifting character of the sand. The dunes range from 10 to 40 feet in height, and many are crescent shaped. They are moving slowly in a direction slightly north of east.

The largest area of dune sand occurs north of Frenchman Hills, where it occupies an area of about 50 square miles, and an area is northeast of Pasco. Smaller bodies are in this same vicinity and elsewhere in the western part of the area.

The dunes are barren of vegetation, though scattered clumps of grass, sagebrush, and sand dock grow throughout the flatter areas. Dune sand areas that have encroached on marsh areas generally support a luxuriant growth of saltgrass and other grasses intervening between the dunes.

Dune sand has no agricultural value aside from the grazing it affords.

ROUGH BROKEN AND STONY LAND

Throughout the western part of the area, particularly on Saddle Mountains, are areas of soil which, owing to the steep and broken character of the slopes, are entirely nonagricultural and have been classed as rough broken and stony land. This class of land consists of badly eroded areas of soils derived from old sedimentary and wind-laid materials and of steep basalt cliffs and slopes. The basaltic cliffs and talus slopes are extensively developed along the northern slopes of Saddle Mountains, and the eroded sedimentary deposits form extensive areas of nonagricutural lands adjacent to Columbia River from Wahluke southward. Bodies of this land in the northern part of the area include eroded soils of the Ephrata series or of residual materials such as occur on the lower slopes of the foothills of Badger Mountains north and west of Ephrata.

This land has no agricultural value aside from its value as grazing land, which is comparatively small.

SCAB LAND

Scab land consists of areas of eroded or of outcropping basaltic lava flow. Many of these are characterized by successive benchlike areas or plateaus separated by basaltic cliffs. The surface is irregular and marked by exposures of barren dark-colored basaltic rock and by angular basaltic boulders and fragments, interspersed with local flats and pockets occupied by shallow soil material. The areas

are much dissected by deep canyons having vertical or steep rock walls and talus slopes.

As occurring in this survey, most of the scab land areas represent land from which former soil materials have been eroded under former climatic and drainage conditions coexistent with greater rainfall, melting glacial ice, and gorged stream channels now represented by greatly diminished or insignificant streams. A few areas occur, however, which have a mantle, ranging from 2 to 3 feet in thickness, of gravel, sand, and cobbles, but such areas have very little value for agriculture and have been included with scab land. Under detailed mapping such areas would be separated as a member of the Ephrata series. In other places the soil material is of fine texture and represents wind-borne material derived from adjacent soil areas.

A large area of scab land occurs south of Wilsoncreek and other areas are in the same general vicinity, a large area is north of Othello, and others lie north and south of Washtucna. Numerous different-sized bodies occur in the eastern, western, and central parts of the area.

A scattered growth of sagebrush and a few bunches of grass are in evidence over the greater part of this land, though in pockets and gullies in the scab land areas, which receive moisture from springs or store it for short periods following rains, grass and other forms of vegetation have gained a foothold. Cattle and sheep graze over the area during the winter and are taken to the mountains for summer pasture. With the exception of local areas of thin soil, few of which cover more than a few acres and are without means of irrigation, this land is of no value for cultivated crops.

SUMMARY

The Columbia Basin area covered by this reconnaissance survey is in the south-central part of the State of Washington and includes all of Franklin County and parts of Adams, Lincoln, Grant, and Walla Walla Counties. The area comprises 4,819 square miles.

The area embraces three physiographic provinces as follows: (1) A high undulating and rolling plateau that includes roughly the eastern half; (2) the so-called "desert plain", which includes the greater part of the western half; and (3) terraces and river flood plains adjacent to Columbia and Snake Rivers and the larger tributary streams.

The area is entirely within the drainage basin of Columbia River. The principal streams tributary to Columbia River are Snake and Walla Walla Rivers and Crab Creek, and there are numerous smaller drainage courses or coulees, many of which have no connection with the main streams and terminate in depressions or on sloping or undulating desert plains.

This part of the State seems to have been visited by white men for the first time about 1804, but it did not assume importance until about 1900, when the growing of grain without irrigation became wide-spread. Wallula is the oldest settlement within the area.

Transportation facilities are good. Three transcontinental railroads cross the area, and a number of branch lines of these systems extend to the smaller settlements. Columbia River is navigable to Priest Rapids and Snake River to Lewiston, Idaho.

Wheat is the principal cash crop, and other small grains grown without irrigation and crops grown under irrigation are less important crops.

The climate is temperate and arid. The summers are hot, the winters moderately cold, the rainfall low, and the wind movement high. Severe electric and hail storms are rare. The average length of the frost-free season is nearly 6 months, although there is a difference of fully a month in the length of this period in different parts of the area. The climate is adapted to the growing of a wide range of crops, although the irregularity in the occurrence of spring frosts in some districts may make the commercial growing of fruits a hazardous occupation. The average annual rainfall ranges from about 6 inches in the southern part of the area to about 12 inches in the northeastern part.

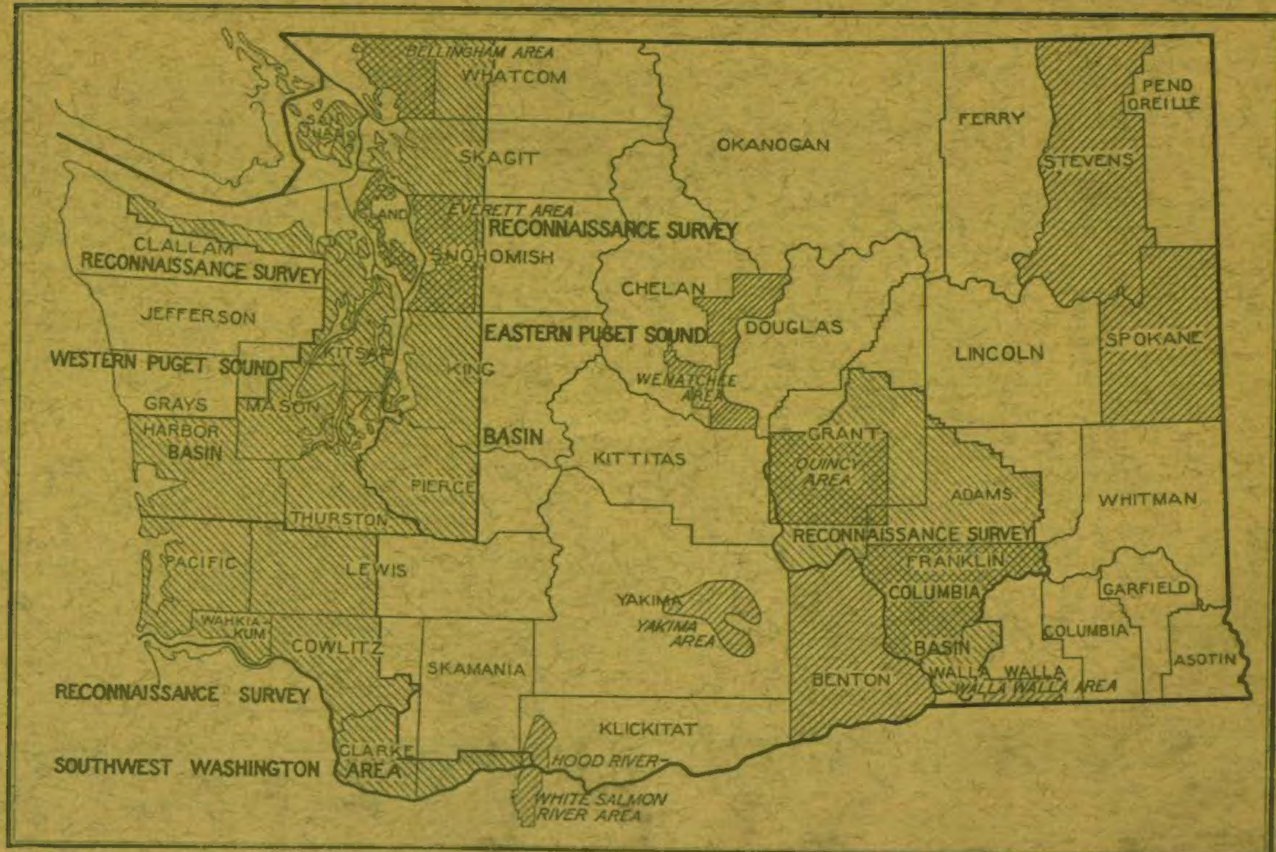
Dry-land grain farming constitutes the most important branch of agriculture. The production of crops under irrigation is well developed within a number of restricted localities, but the irrigated areas and the returns from them are small compared with those of the dry-farming grain districts. Apples and pears are the principal fruits grown under irrigation; alfalfa is an important crop within the irrigated districts; and small fruits, truck crops, and melons do well where water is available. All of these crops are of considerable local importance. Dry-land wheat farming is now developed to its maximum extent. The extension of the irrigated area will remain practically stationary until some comprehensive and practical plan of irrigation is developed to cover the lands that are now devoted to the production of grain without irrigation. The grazing of cattle and sheep is of local importance.

The soils within the area are derived from loessial, wind-blown, and sedimentary materials. The loessial materials, which have contributed the greater part of the soils, form the high rolling and undulating plains that cover practically all the eastern half of the area; the wind-blown soils constitute an extensive group of soils in the western and southern parts; and the sedimentary soils are derived from materials of both old and recent accumulation and are most extensively developed in the western and southern parts.

The loessial soils are included entirely within the Ritzville series. The soils derived from wind-blown materials include the soils of the Winchester, Quincy, and Koehler series. The soils derived from the older sedimentary materials are correlated in the Sagemoor, Ephrata, Warden, and Burke series. Those soils which have been derived from materials of recent accumulation are included in the Ringold, Pasco, Beverly, Esquatzel, Washtucna, Naylor, and Red Rock series. Muck and peat, dune sand, rough broken and stony land, and scab land constitute a group of miscellaneous soil materials which do not conform to the series and type classifications. They are mainly nonagricultural.

Authority for printing soil survey reports in this form is carried in Public Act No. 269, Seventy-second Congress, second session, making appropriations for the Department of Agriculture, as follows:

There shall be printed, as soon as the manuscript can be prepared with the necessary maps and illustrations to accompany it, a report on each soil area surveyed by the Bureau of Chemistry and Soils, Department of Agriculture, in the form of advance sheets bound in paper covers, of which not more than two hundred and fifty copies shall be for the use of each Senator from the State and not more than one thousand copies for the use of each Representative for the congressional district or districts in which a survey is made, the actual number to be determined on inquiry by the Secretary of Agriculture made to the aforesaid Senators and Representatives and as many copies for the use of the Department of Agriculture as in the judgment of the Secretary of Agriculture are deemed necessary.



Areas surveyed in Washington shown by shading.

Detailed surveys shown by northeast-southwest hatching; reconnaissance surveys shown by northwest-southeast hatching; crosshatching indicates areas covered in both ways.

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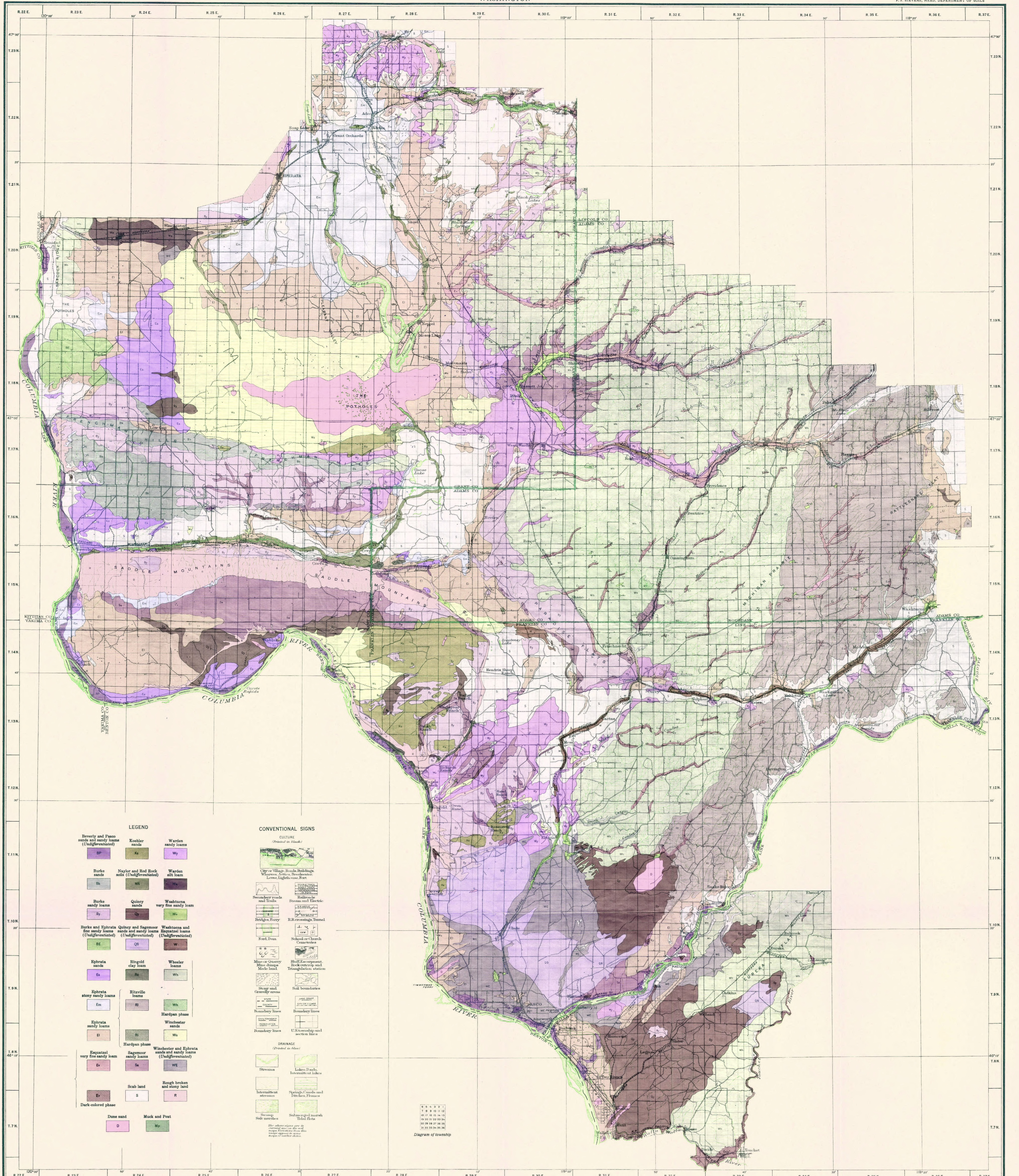
U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF CHEMISTRY AND SOILS
HENRY G. KNIGHT, CHIEF
A. G. Mc CALL, CHIEF, SOIL INVESTIGATIONS
CURTIS F. MARBUT, IN CHARGE SOIL SURVEY

SOIL MAP

RECONNAISSANCE SURVEY
COLUMBIA BASIN AREA
WASHINGTON

STATE COLLEGE OF WASHINGTON
AGRICULTURAL EXPERIMENT STATION
E. C. JOHNSON, DIRECTOR
F. J. SIEVERS, HEAD, DEPARTMENT OF SOILS



Macy H. Lapham, Inspector, District 5.
Soils surveyed by A. T. Strahorn, in charge, E. J. Carpenter, W. W. Weir, Scott Ewing, and H. H. Krusekopf, U. S. Department of Agriculture, and A. F. Heck and H. A. Lunt, State College of Washington.

BASE MAP IN PART FROM U. S. GEOLOGICAL SURVEY SHEETS

Scale 1 inch = 3 miles

Field Operations
Bureau of Chemistry and Soils
1929